# KARST TOPOGRAPHY AS AN INFLUENCE ON LAND USE IN WEST CENTRAL FLORIDA

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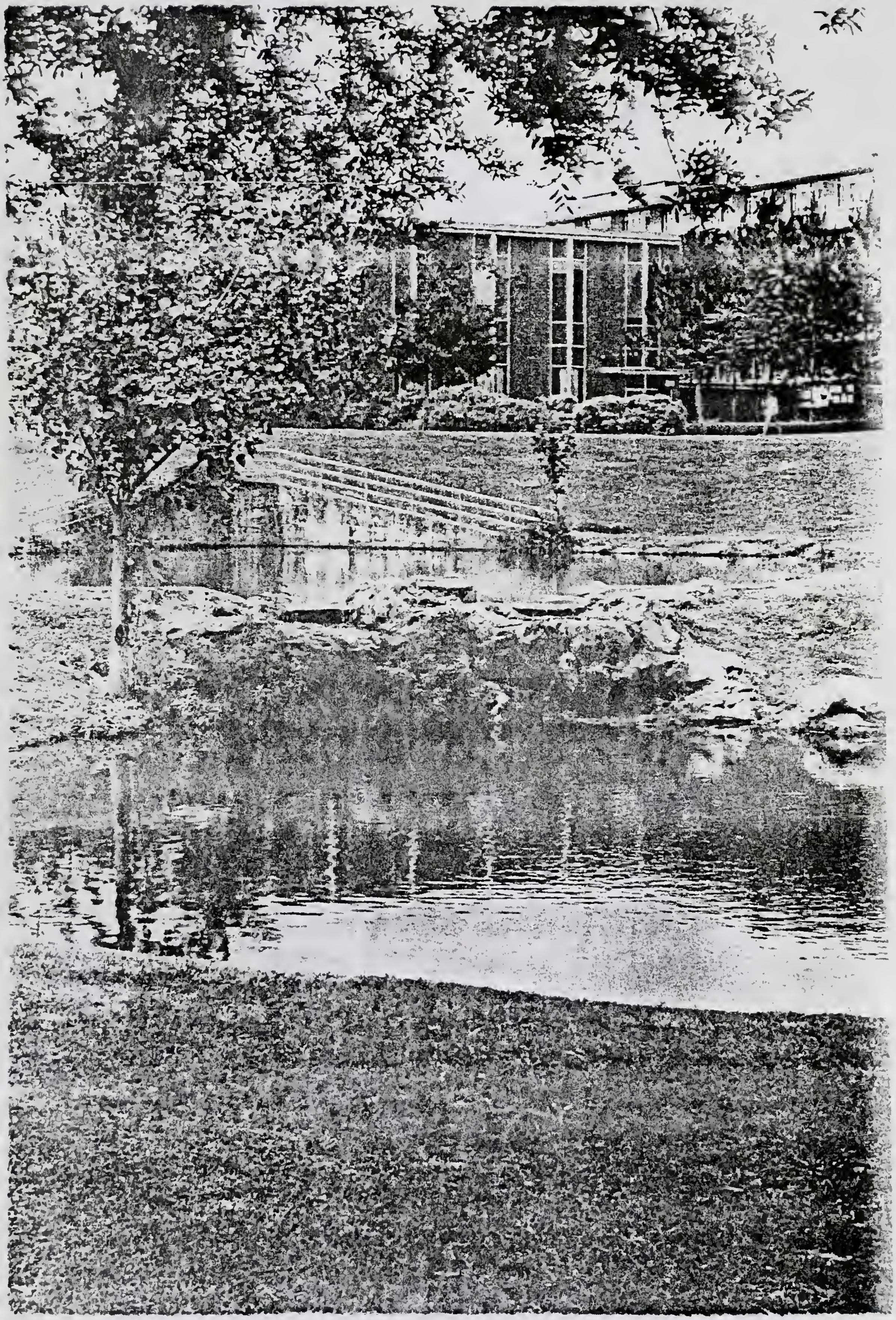

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# TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

# LIST OF TABLES

LIST OF TABLES (continued)

## LIST OF FIGURES

LIST OF MAPS

Abstract of Dissertation Presented to the
Graduate Council of the University of Florida in Partial
Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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A limestone terrane is a distinctive landscape with a particular set of contingencies to which man must adapt. The most important adaptation is in man's use of the land. Limestone outcrops cover several million square miles of the earth's surface, and they can vary extraordinarily from place to place. Rock solubility is the dominant factor in the formation of karst landscapes.

Karst is found extensively in North America, and most of Florida is underlain by limestone sediments deposited during the Cenozoic Era. Eight counties of west central Florida have limestone outcrops of Eocene age, which constitute one of the largest contiguous exposures known anywhere. These lands were selected for study, in a treatment which is original for the area and for its scope, depth, and broad use of today's geographical methods, to evaluate the influence of karst on the use of the land.

Sinkholes and sporadic subsidence of land is commonplace throughout. Other karst features include springs of varying size and water-filled depressions. Land use has always shown some shifting, although

the shifts tend to remain within the boundaries of the original natural vegetation, so that the overall percentages of land in crops, pastures, and forests remain fairly stable. Yields on the limestone plains, where soils are thinnest, are substantially lower than elsewhere in the Gulf Coastal Plain Province.

Sinkhole counts were made to establish density ratios, with counts up to 24 large sinkholes per square mile on the Bell-Trenton-Chiefland Plain. These and other subsidence features form a hazard which the inhabitants perceive at only a low level. The hazards accumulate however, and when their effects are summed up, they cause the death of livestock, imperil humans, and add to farming and production costs. Sinkholes degrade highways and are an added expense in road maintenance. Karst features also add to building costs, requiring special exploration. The accessibility of surface pollutants to deep aquifers through solution ducts is a threat to remote farms, as well as to major centers such as Gainesville and the University of Florida.

Population levels have tended to be static in the study area, owing in large part to the limited subsistence farming which is the base of the region's economy. Karst as a resource has provided supplemental wage employment from time to time, in the form of rock and mineral extractive operations. Springs assume some economic importance as resort sites, while still others have seen intensified use as state-sponsored recreational parks. A new factor is the development of residential communities for sale to out-of-state persons, using the presence of lakes as a chief sales attraction. Such land

use is new to the area, and can have a major impact on the demography and economics of the region.

In overview, the chief influence of karst is seen to be a limiting one. The areas were settled sparsely, as second-choices after more desirable lands were taken up, remained as small economic units and limited the production and growth of the region. Limited crop yields persist to the present, and farming is either marginal or declining. There is much natural beauty in the region, however, and new communities using karst features may completely shift the basis of land use in the future.

# CHAPTER I

# INTRODUCTION

## The Study and Its Objectives

Physical or natural factors of the environment include climate, topography, soils and water cycles. These factors are interrelated in their effect on man and in his response to the environment. One of the more significant is topography, to be discussed here as it affects man's use of the land for his home and work. The physical milieu sets limits on human activity and provides the framework within which man must make his way. He, in turn, modifies or disrupts the natural operation of the physical factors. A limestone terrane is a distinctive landscape offering a particular set of contingencies to which man must adapt, his response being most measurable in the observation of his use of the land.

The major objective of this study is to collect and organize selected information and data concerning the karst country of west central Florida for the purpose of gaining an understanding of the effect of solution landforms on land use in the region. This region is a limestone terrane, chiefly the Eocene outcrop on the axis of the Ocala Uplift. The counties referred to in this study lie wholly or largely within the most extensive contiguous exposure of the Ocala Group in Florida.

Secondary objectives are as follows: to examine the geomorphology of the region in order to contribute to existing works concerning the karst features present; to assay the peculiar impact of karst landscape upon patterns of agriculture; to analyze economic circumstances as in-

fluenced by limestone topography; and to relate the study to certain recent investigations concerning environmental hazards.

## Overview of the Study Area

An introduction to the eight-county region shows Dixie, Levy, and Citrus counties as coastal lands almost wholly representative of the Eocene outcrop. Lafayette, Gilchrist, Alachua, Marion, and Sumter counties are more or less representative. Outliers of Miocene deposits remain to a significant extent as the strip of Alachua Clay or Hawthorne deposits running through the area.

As much as possible, any discussions or descriptions included in the study will be relative to karst. Difficulty arises with appraisal of certain economic factors such as forest products or industrial output, but emphasis will be on the more direct influences such as limestone evaluated as a resource.

This introduction to the study area will briefly describe location, population, climate, soils and vegetation, with the view that an understanding of the regional geography is basic to understanding the relationships between land use and karst. A close examination of the geomorphology of the area is included as a major component of this work.

### Location

The study area comprises over six thousand square miles in central peninsular Florida, approximately between 29° and 30° north latitude (see Map 1). The region borders on the low-energy Gulf Coast of the upper peninsula. The counties lie in the physiographic province of the Coastal Plain, as defined by Fenneman,[1] but extend into the higher areas of "upland" Forida known as the Central Florida Ridge (see Map 2). The

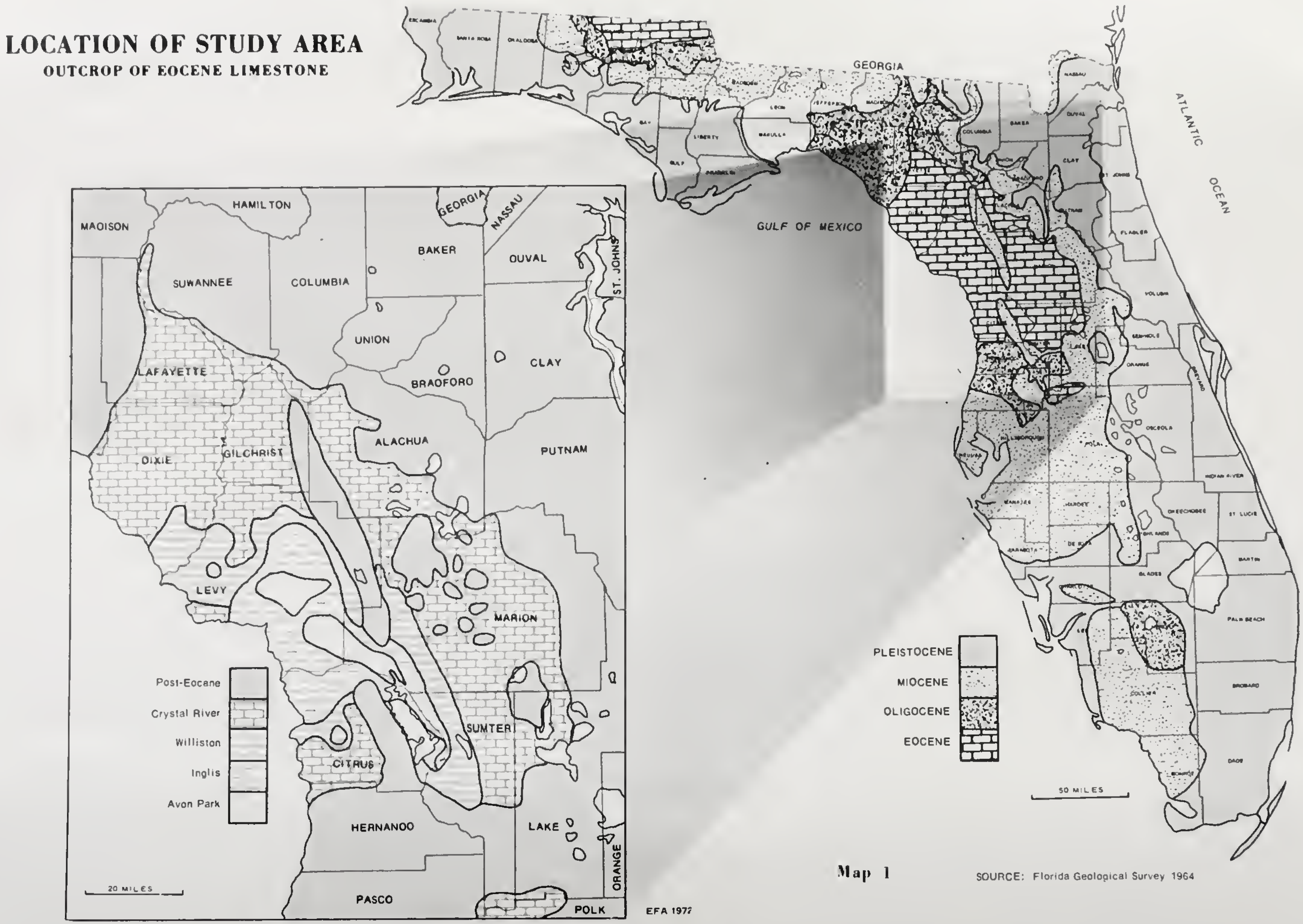
Eocene-age outcrop is rimmed on the east by Miocene deposits and on the north and south by Suwannee limestone of Oligocene age.

The study area includes the Steinhatchee River, some of the Suwannee River, and parts of the Santa Fe River, the Oklawaha River, and the Withlacoochee River. The Waccasassa River is entirely within the study area. The research is focused on the "heartland" of this physical region, the limestone plains stretching north-to-south through Gilchrist, Levy, Alachua, and Marion counties. Chiefly agricultural areas, these plains offer individual examples for a closer view. In addition to the selected case studies, use was made of the Conservation Needs Inventories made in 1958 and 1966 by the United States Soil Conservation Service. The focus was again on the limestone plains as the central and most influential sub-region.

## Population

The area has never supported a large population and has grown only very slowly since the first American settlement. The earliest inhabitants were Indians of the Archaic Phase who subsisted by hunting, fishing, and foraging.[2] Traces of this early and intermittent land use are found along the coast and on the banks of streams and springs. Mounds of shells remain today, and there is evidence of former coastal occupation by Indians in the "drowned" shallows of the Gulf shore. The Apalachee and Timucua of North Florida reached a near-civilization grouped in permanent towns with palisaded walls and large houses. They grew corn in extensive fields surrounding the villages.[3]

The earliest white men in the area were those of the party of Panfilo Narváez, a Spanish explorer journeying northward from Tampa Bay to

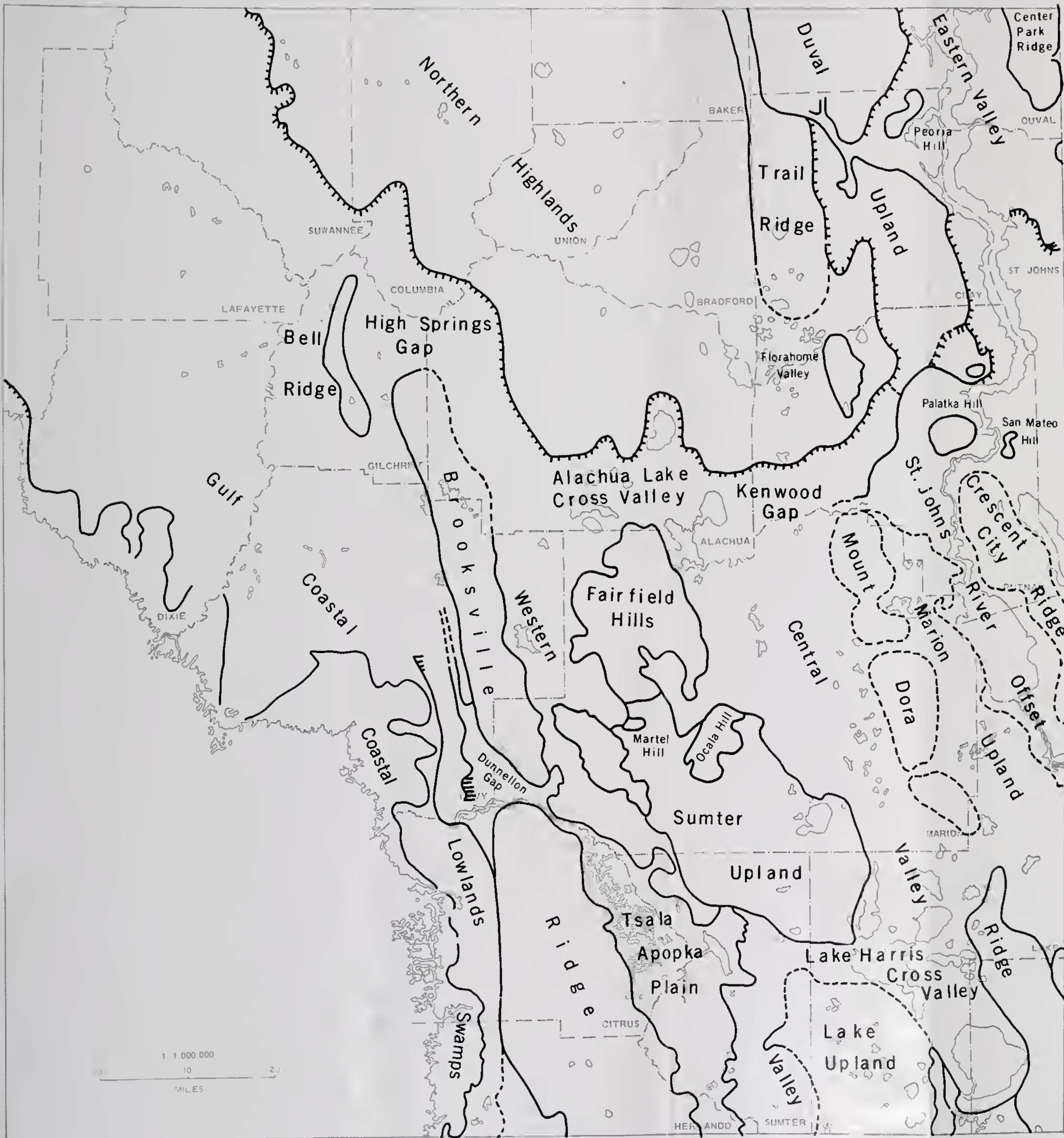



**Map 1**

SOURCE: Florida Geological Survey 1964

Surface and Near-Surface Eocene Limestone (Study Area)

## REGIONAL LANDFORMS




Map 2

Source: Florida Geological Survey

the vicinity of Tallahassee. Narváez, as did de Soto later, likely traversed ancient Indian trails. Some of these same trails, along favorable topography, later became the early roads through the region. Spanish missions were emplaced as far west as present-day Alachua County by 1606, but it is thought that they survived only about a hundred years.[4] There are practically no remains of these settlements today, but evidence indicates that the early Indians and the Spanish colonists as well subsisted on diets of corn, pumpkins, beans, game, and fish.[5]

With the decay of the missions and the mounting trouble with the English, the sparsely scattered Spanish occupants vanished almost without trace. Activity by white men was at that time located chiefly along the coast. Though back in Spanish hands yet another time, west central peninsular Florida was little influenced by Spanish culture. Even with increasing economic and military movement in Florida, the limestone plains of the central area remained almost unaffected, probably because of the lack of surface streams for inland navigation. With the gradual settlement by farmers, the area became part of the Middle Florida agriculture belt.[6] The Lafayette land grant, a gift to the Marquis in 1824, did much to advertise the region to settlers, though Lafayette himself never saw this land.

Transportation into the interior was aided as roads were built to connect forts during the Seminole Wars. Congress authorized a road from Pensacola to St. Augustine which later became known as the Bellamy Road. Portions of this roadway remain today, with one such marking the use of the "natural bridge" route over the Santa Fe River. The town now named Lake City was once called Alligator, leading to the term Alligator Road for part of the route.

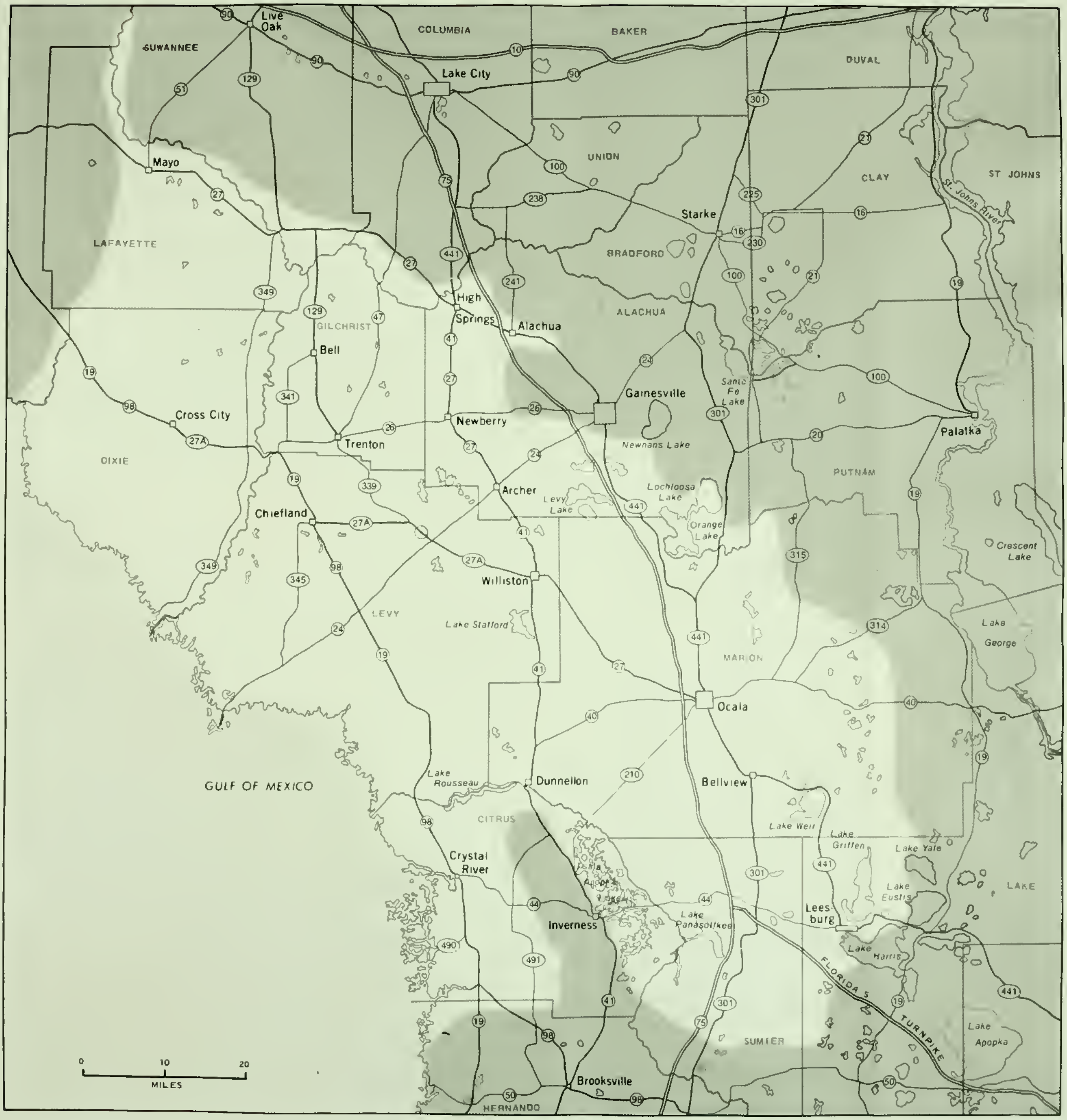
Cotton was grown throughout the region but subsistence farming was the most prevalent land use. The soil was quickly depleted, requiring more and more clearing of "new" land. The coming of the railroads led to exploitation of the forests for lumber and turpentine. The region remained in general farming with little urbanization through the period of the War Between the States and even into the twentieth century. Urban places are few even today with Gainesville and Ocala (neither actually wholly in the study area) being the largest (see map 3). Population statistics illustrate the economic situation in these counties (see Table 1), not especially prosperous when considered in relation to the rest of Florida.

Climate, Soils and Vegetation

In the study area the average January temperature is close to 58° F. and the average July temperature is 80° F. There is frost in winter, so that tropical conditions do not exist; but cold spells rarely last more than three days. Except in coldest periods, the temperature is above freezing in the daytime. Maximum rainfall occurs usually in June and July, and the minimum is in October, November, and December; the average annual rainfall amounts to approximately 50 to 55 inches. Relative humidity is high and heavy morning fogs occur occasionally. There is a growing season of approximately 290 to 310 days per year.

The soil map of Florida indicates 34 soil associations and three miscellaneous land types in the state as a whole. The associations are composed of soils with similar origins and characteristics. Many such associations are found in the study area, but only the principal groupings

# POPULATION CENTERS and MAJOR HIGHWAYS

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**Map 3**

Source: Base Map, Florida Geological Survey

are shown on the soil map (see Map 4). The soils indicated are predominantly sandy and developed on materials little altered by climate and vegetation. Variations appear to reflect parent material, because climatic differences are not pronounced enough to cause contrasts within the small region. The parent material is principally limestone and sand with some clay and alluvial deposits present also.

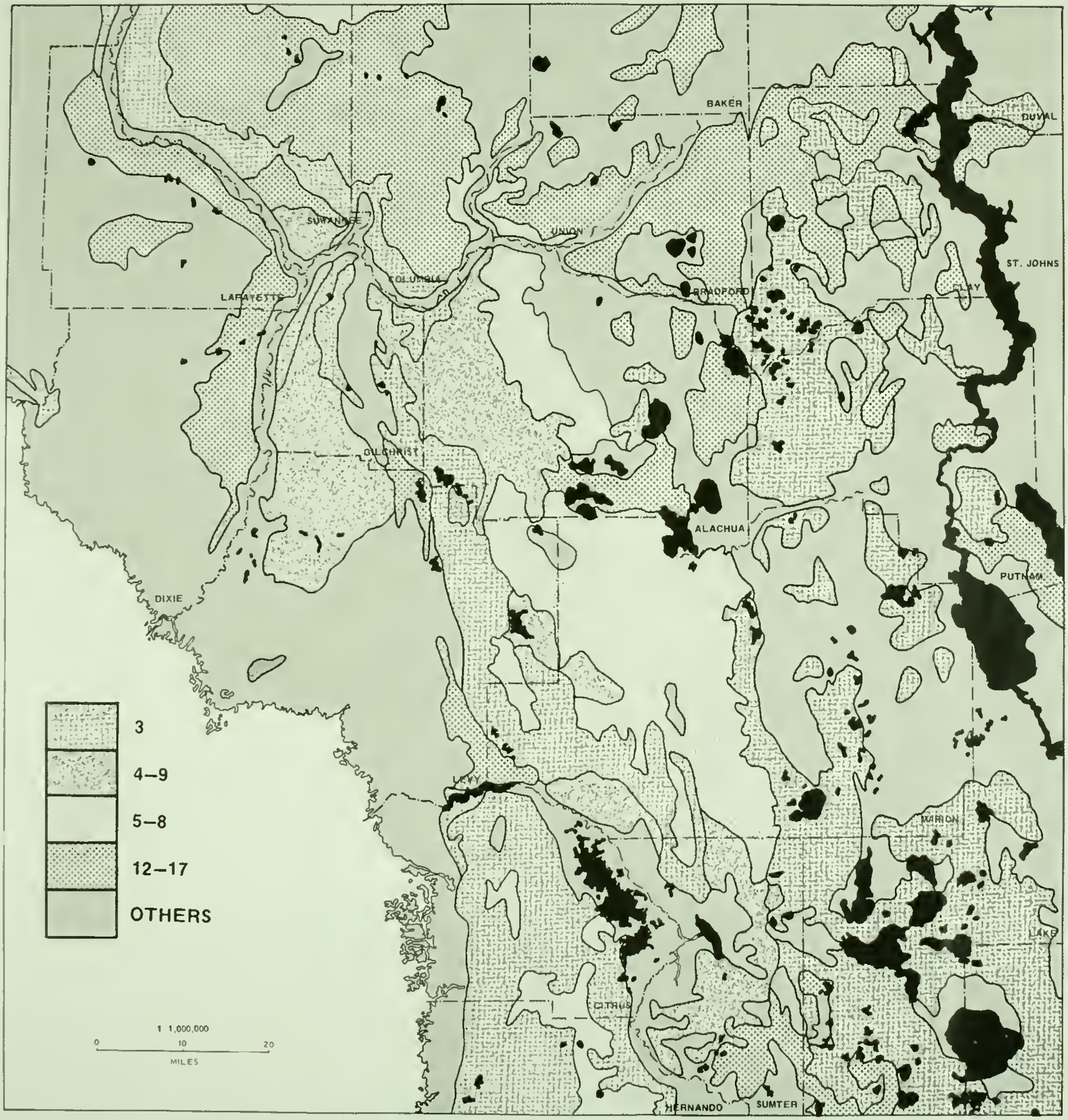
Since the study area encompasses parts of the Central Florida Ridge and the Coastal Plain Province, the soils have somewhat greater differences than might be expected in a small area. However, the underlying limestone with its high porosity predisposes an overall excessively drained aspect except in areas with clay or silt. The groupings in the area range from solid dominantly thick to moderately thick acid sands (formed on Pleistocene sands, dunes and terrances) to soils dominantly thick to thin sands influenced by alkaline materials.[7]

The surface of the region is nearly flat to gently sloping and the native vegetation varies with soil types and drainage. High hammock land occurs in the eastern parts characterized by a mixture of hardwoods, pines, shrubs, and grasses.[8] Some low hammock land with heavier plant growth is found near lakes in the southern part of the region, but dominant vegetation throughout the entire area is pine woods. Stands of turkey oak and longleaf pine are typical of the sand hills.

There are few remains of native vegetation or virgin forests. Practically all of the area has been farmed or logged off. In the limestone plains of the Bell-Trenton-Chiefland and High Springs-Newberry-Archer-Williston-Reddick areas, the presence of clumps of trees, especially live oaks, usually indicates sinkholes or outcrops of limestone.

# PRINCIPAL SOILS

## NORTHWEST CENTRAL FLORIDA




**Map 4**

Source: General Soil Map of Florida

Table 1 Population Statistics in Eight-County Study Area

| | Total Population | | | Urban | Rural-1970 | | |
|---|---|---|---|---|---|---|---|
| County | 1900 | 1940 | 1970 | 1970 | Total Rural | Places of 1000 to 2500 | Other Rural |
| Alachua | 32,245 | 38,607 | 104,764 | 72,116 | 32,648 | 4,625 | 26,023 |
| Citrus | 5,391 | 5,846 | 19,196 | -- | 19,196 | 3,995 | 15,201 |
| Dixie | NA | 7,018 | 5,480 | -- | 5,480 | 2,268 | 3,212 |
| Gilchrist | NA | 4,250 | 3,551 | -- | 3,551 | 1,074 | 2,477 |
| Lafayette | 4,987 | 4,405 | 2,892 | -- | 2,892 | -- | 2,892 |
| Levy | 8,603 | 12,550 | 12,756 | -- | 12,756 | 3,904 | 8,852 |
| Marion | 24,403 | 31,243 | 69,030 | 27,872 | 41,158 | 1,146 | 40,012 |
| Sumter | 6,187 | 11,041 | 14,839 | -- | 14,839 | 2,082 | 12,757 |

Source: Florida Handbook (1970)
Source: Abstract of the Twelfth Census, 1900 Washington, Government Printing Office, 1904
Source: The World Almanac and Book of Facts, 1950 NY World Telegram

Soils in general show the effects of erosion. In certain local areas, wind is a chief agent in the removal of the topsoil. The landscape is often beautiful, with a "rolling" aspect such as that found in the Bluegrass region of Kentucky. Green pastures with small and large clumps of trees and vegetation are typical (see Figure 1). The last forests of pines were cut chiefly in the 1920's and 1930's, During the 1930's wind erosion became such a severe problem on land stripped of vegetation that the area was sometimes compared to the dust bowl of the west. The problem was greatly reduced by the introduction of Pensacola Bahia grass as cover for the soil.*.

The well-known World War II writer, Ernie Pyle, travelling through this region in 1935 on Highway 41, noted the wind erosion and the marginal character of the subsistence homesteads.[9] Pyle's observations are quoted verbatim in deference to his unique powers of description.

> We drove up through north-central Florida toward Georgia. That part of Florida is no more like the winter-resort ads than an electric razor is like the Brooklyn Bridge. It is plain old deep South, except that it isn't so good-looking; it lacks the luxuriant vegetation, the greenness and freshness. It is a land of gray sandy soil, brown scrub pines, little farms, and many shacks. It is country that makes you melancholy.
>
> The wind was blowing a steady, insistent gale. It was hot with an uncanny, foreboding heat. You had a feeling that this wind would slowly, relentlessly blow away north Florida. Queer clouds were in the sky. And then we began to run through dust storms. From every open field the dust streamed across the road; from big fields it rose high into gray clouds. We had to keep running up the windows, and we were soon dusty all over and grit was in our teeth. Although we never had to turn on our lights, as we did in west Kansas, we said to ourselves, "This is an incipient dust bowl. It has every earmark of the desolated areas in Kansas and Oklahoma.

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*State Office Agricultural Stabilization Conservation Service.

The soil is light, and lifts more easily than the western loam. The timber is scrubby, and they're clearing too many fields. If the government doesn't start doing something, they'll be making moving pictures of the great Florida dust bowl in a few years."

We stopped in a town for lunch. I asked the woman at the counter if it blew like this every spring. She said, "Oh, no, this is the first wind we've had." I went up to two men on a street corner. They were farmers-typical overalled cracker farmers. I talked to them about the possibility of this section's blowing away.

"No, no," they said, "this don't amount to nothin'. Next month will be worse than this, but this country ain't blowin' away. We get lots of rain here, better than fifty inches a year. And there's lots of springs hereabouts. No, there's no danger of a dust bowl here."

This was corn, tobacco, and peanut country. I talked with the farmers a long time. I couldn't get the dust-bowl idea out of my head-for I had seen the real dust bowl, and they hadn't. I put one last question: "Have you ever had any bad droughts around here?"

"No, sir," one of them said, "we've never had a single one, except once. That was pretty bad. The water got up over the highway, and they had to rebuild the road. It drowned out all the crops around here. The water was even right up in the streets here in town."

That seemed to settle the question. I had intended asking if they ever had any floods, but after that I didn't see any sense in it.

Double rows of planted pines outline many fields, evidence of other efforts to slow the relentless winds. They add to the beauty of the landscape as they bound the secondary roads and fencerows. Geometric rows of huge acreages of planted pine add green to the drab fields between.

Farms today are dispersed rather evenly throughout the limestone plains and livestock graze in large fields. Corn is a chief crop because it is required for feed for hogs, an important animal in the economy.

Figure 1 -- View of Typical Landscape of Limestone Plains of Williston

Karst landforms are widespread except in the flatwoods areas underlain by clastic sediments in abandoned river valleys or in graben-like structures. Sinkholes and outcrops are the chief karst features and are numerous in the plains area where there is no surface drainage network.

## Relevant Studies of Karst Areas

The history of this study can be traced through the published literature and unpublished research accounts. The materials generally fall into one of two categories--subsurface geology and geomorphology. Only a few studies have been made which attempt to correlate the physical milieu with cultural, or human, aspects. Most of these refer to climate as a major influence on man. Rarely does an author pursue his study into the increasingly complex relationship between physical factors of soil, vegetation, slope and drainage, and man in his work on the earth. That a relationship exists is of course obvious, but there are many unanswered questions concerning the degree of significance.

The earliest recorded scientific analysis of the characteristic limestone landscape is probably that of Lamarck.[10] Well-known in other fields, he made this single contribution to geology in Hydrogeology, published at his own expense in 1802. He states his conclusions concerning the origin of limestone rocks, drawn from careful observations of fossils and stratigraphic relationships. His statements about geologic time are surprising, considering the religious climate of his day. His understanding of the various "displacements" of the ocean basins along with an awareness of subaerial erosion processes offer a beginning for analysis of limestone terranes.

A century of increasing study of the earth's surface finally produced a classic in landform analysis. William Morris Davis, well known as "the great definer," coined a wealth of descriptive terms for the study of structure, process, and stage by geomorphologists. In this vein Jovan Cvijić in 1918 adapted the cycle of erosion to a limestone landscape of Yugoslavia. His conception of the cycle as applied to a karst region is most important today for the substantive vocabulary, imparting an invaluable unity to the students of solution geomorphology. For instance, this is the first use of such nonfamiliar terms as "ponor" or "polje." Many of the words are of Serbo-Croat derivation but French and German nouns are also employed.

E. M. Sanders (1921) condensed and summarized Cvijić on karst in the Geographical Review, thus establishing a core vocabulary directed toward physical geographers.[11] Much more recently, H. Lehmann (1960) described attempts at compilation of a uniform and descriptive karst vocabulary for the Commission on Karst Phenomena on the occasion of the XIX International Geographical Congress.[12] The recommendation that an International Atlas of Karst be prepared did not come to fruition, but the United States Geological Survey did publish a Glossary of Karst Terms (1970) by Watson Monroe.[13] This work is a synthesis of definitions of karst words as they are generally used, without significant departure from the vocabulary of textbooks by Lobeck or Thornbury.

The understanding of patterns of world karst depends heavily on an agreement as to the meaning of terms used in the literature. With the latest work by Monroe there has evolved at least an English language karst vocabulary. The matter of definition gains importance when attempts

are made to enumerate karst features or to tabulate sinkhole densities. Counts of Indiana and Kentucky sinkholes have been occasionally attempted. Some examples are "Land of Ten Thousand Sinks" in Transactions of Kentucky Academy of Science (1924),[14] or "Sink Holes" in This Sculptured Earth (1959).[15] (See Table 2.)

As stated before, publications are numerous concerning the geology of the solution landscape. Notable among these are Cotton (1941) on "Limestone Landscapes,"[16] Swinnerton (1942) on "Hydrology of Limestone Terranes,"[17] and Stringfield and Le Grand (1971) on Artesian Water in Tertiary Limestone in the Southeastern United States (1966).[18] These geological publications offer much in the way of background information for a study of a limestone terrane but do not include the cultural aspects so vital to a determination and analysis of use of the land. A study by Wellington Jones, "A Method of Determining the Degree of Coincidence in Distribution of Agricultural Uses of Land With Slope-Soil-Drainage Complexes" (1930) compares features on topographic maps with distribution of crops and other agricultural land uses.[19] More recently Woodford Garrigus describes relief of land as a determinant of use in "Roughness of Terrain as a Factor in the Areal Variation of Agricultural Productivity in Ohio" (1965).[20] These publications do not refer specifically to limestone terranes, but they serve as background material for the type of study attempted here.

Dr. Garrigus offers an interesting justification for his study, as follows:

> ---it may be said that the results of this investigation should prove instructive in the study of the association between land use and land surface conditions as that association might be taken up in connection with physical geography, economic geography,

Table 2 Kentucky Sinkhole Enumeration

| Topographic Sheet | | Number of Sinkholes |
|---|---|---|
| Mammoth Cave | | 2,833 |
| Brownsville | | 1,150 |
| Bowling Green | | 2,563 |
| Princeton | | 1,429 |
| Monticello | | 1,096 |
| | Total | 9,071 |

Largest in area is on Brownsville Sheet, 3,114 acres. Author estimates that the mapped areas of the Mississippian Plateau in Kentucky contains between 60,000 and 70,000 sinkholes of varying size and description.

Source: "Land of Ten Thousand Sinks" W. R. Jillson Kentucky Academy of Science (1924).

> agronomy, or any number of other subjects. The results may be of general interest even though not used for any specific purpose.

More practical gains might be expected to come from a much more intensive study of land use in relation to land forms, including not only a detailed examination of the areal association between the two, but including also an attempt to discover so far as possible the causal relationships: Just how, precisely, does the form of the land surface act to influence the various kinds of land use?

Most helpful is an assemblage of research directly based on the limestone landscape. A pioneer in this respect is Carl Ortwin Sauer with his Geography of the Pennyroyal (1927).[21] This book is a study of the influence of geology and physiography upon the industry, commerce, and life of the people of a Kentucky area. He uses the limestone landscape as a basis for regional unity and develops this idea through description of historical land uses.

Actually more geological than geographical in scope is a recent work by Placido La Valle (1967).[22] His purpose was to analyze spatial patterns of karst features, but his emphasis was on elongation and orientation of sinkholes rather than on uses of the land. A more classic geographical approach is found in "The Central Kentucky Karst" by White, Watson, Pohl, and Brucker (1970).[23] This accurate and descriptive work features the influence of climate on karst processes and the rates of denudation of karst plains in Kentucky.

Doubtless the most significant and most pertinent recent research in a similar vein, yet wider scope, is a dissertation by James M. Goodman (1962) describing yet again the Pennyroyal area and analyzing

the influence of its landscape on agricultural land use and productivity.[24] This is a case study approach dealing with an area of outcropping limestone in the Kentucky karst. Goodman has defined ten different terrane types from various combinations of soil, drainage, slope and lithology. These types form a framework for examination of land use and agricultural productivity. Patterns and variations for each terrane type were determined and compared with crop yields and land values.

It is evident that a study of this type has not yet been made of Florida karst. The range of physiographic terrane types is not as large as that of other karst areas because of the relatively low relief, and also the soils are more homogeneous as well. On the other hand, the variety of expression is surprising and the sinkholes vary widely in size, shape, and depth.

NOTES TO CHAPTER I

[1]N. M. Fenneman, Physiography of the Eastern United States (New York: McGraw-Hill Book Co., 1938), p. 46.

[2]Gordon E. Bigelow, "History of Man in the Oklawaha Valley," Environmental Impact of the Cross-Florida Barge Canal (Gainesville: Florida Defenders of the Environment, 1971), p. 47.

[3]Florida Handbook (Tallahassee: The Peninsular Publishing Company, 1971), p. 293.

[4]Charlton W. Tebeau, A History of Florida (Coral Gables: University of Miami Press, 1971), p. 53.

[5]Ibid., p. 52.

[6]Ibid., p. 125.

[7]Florida Agricultural Experiment Station, Principal Soil Areas of Florida, a Supplement to the General Soil Map (University of Florida, 1967), p. 15.

[8]Ibid., p. 4.

[9]E. T. Pyle, Home Country (New York: William Sloan Associates, Inc., 1947), pp. 340-341.

[10]J. B. Lamarck, Hydrogeology (Urbana: University of Illinois Press, 1964), first published at the author's expense in 1802.

[11]E. M. Sanders, "The Cycle of Erosion in a Karst Region (After Cvijic)," The Geographical Review (1921).

[12]H. Lehmann, "Introduction," Second Rapport of the Commission on Karst Phenomena, XIX International Geographical Congress, Norden (1960), p. 6.

[13]Watson Monroe, A Glossary of Karst Terminology, United States Geological Survey Water Supply Paper 1899-K (1970).

[14]W. R. Jillson, "Land of Ten Thousand Sinks," Sketches in Geology (Louisville: C. T. Dearing Printing Co., 1928, Reprinted from Transactions, Kentucky Academy of Science, Vol. I, 1924),pp. 143-144.

[15]John A. Shimer, "Sink-holes," This Sculptured Earth: The Landscape of America (New York: Columbia University Press, 1959), p. 238.

[16]C. A. Cotton, "Limestone Landscapes," Landscape (Cambridge: University Press, 1941).

[17]Allyn Swinnerton, Hydrology of Limestone Terranes, Physics of the Earth IX, Meinzer, ed. (New York: McGraw-Hill Book Co., 1942).

[18]V. T. Stringfield and H. E. Le Grand, Artesian Water in Tertiary Limestone in the Southeastern United States, United States Geological Survey Professional Paper 517 (1966).

[19]W. D. Jones, "A Method of Determining the Degree of Coincidence in Distribution of Agricultural Uses of Land with Slope-Soil-Drainage Complexes," Transactions, Illinois Academy of Science, Vol. 22 (1930).

[20]W. M. Garrigus, "Roughness of Terrain as a Factor in the Areal Variation of Agricultural Productivity in Ohio," paper presented at the Annual Meeting of the Association of American Geographers, Columbus, Ohio (1965).

[21]Carl Ortwin Sauer, Geography of the Pennyroyal (Frankfort: The Kentucky Geological Survey, 1927).

[22]Placido La Valle, "Some Aspects of Linear Karst Depression Development in South Central Kentucky," Annals of the Association of American Geographers, Vol. 57, No. 1 (1967).

[23]William B. White, Richard A. Watson, E. R. Pohl, and Roger Brucker, "The Central Kentucky Karst," The Geographical Review, Vol. LX, No. 1 (1970).

[24]James A. Goodman, Physiography and Agricultural Land Use in a Portion of the Pennyroyal Region in Warren and Edmonson Counties, Kentucky (Northwestern University Dissertation, 1963).

# CHAPTER II

# PHYSIOGRAPHIC BACKGROUND FOR THE STUDY

## Karst Areas of the World

Carbonate rocks constitute about five to ten percent of world-wide sedimentary rocks; and outcrops of limestone measure several million square miles of the earth's surface.[1] The distinctive limestone terrane can be found on every continent, but quite often it varies extraordinarily from place to place. Rock solubility is the primary element in the formation of karst landscapes. Certainly the carbonate rock, or other soluble material, must be present for karstification to occur. Other important considerations include rock structure and climate.

World karst areas have been studied by workers and comparisons and contrasts recorded. Some of the areas most often noted for research projects outside the United States are listed in Table 3.

Karst is considered to be the surface expression of solution phenomena and is a descriptive geomorphological term. Generally it is "sinkhole topography" named after the Yugoslavian word "kras" meaning "stone."[2] The Italian place-name "Carso' and the French word "Causses" are sometimes regarded in the generic sense as equivalent to karst. The classic region for the observation of karst is the plateau of the western Balkans, the study area for Jovan Cvijić who established a substantive vocabulary for his description of a "karst cycle."[3]

Table 3 Karst Areas of the World (outside of the United States)

Middle America and the Caribbean

Northern Yucatan and Tabasco (Mexico)
Jamaica
Western Cuba
The Bahamas
The West Indies
Bermuda

Europe

The Pennines of Yorkshire and Derbyshire (England)
The Mendyes and South Wales
County Clare in Western Ireland
Spanish Andalusia
The Grand and Petits Causses (Southern France)
The Dinaric Alps (Yugoslavia)
Greece
Arctic Spitsbergen

Southeast Asia and Oceania

South China
North Vietnam
The South Coast of Central and East Java
Southwestern Celebes
Central New Guinea
Western Australia
North Canterbury, New Zealand

Nearly every country has its own individualized set of karst terms coined to fit its particular landscape features. In the presence of carbonate rocks, a variety of geologic and hydrologic features account for the almost infinite variation of karst expression. It should be remembered that there are also innumerable areas where karst features are present as surface landforms, but do not dominate the landscape. These areas are not included in this review.

It has been noted that world karst areas vary with climate and rock composition and structure. There may be well-drained uplands completely bare of soil, or jungle-covered lowlands mantled with thick organic muck. The rocks may be flat-lying to steeply dipping. The presence of caves may or may not constitute a karst terrane, for it is the surface expression that is being described.[4]

## Karst Areas in the United States

Karst terranes develop most efficiently when certain factors in addition to the presense of carbonate rocks prevail. The soluble rocks should be dense, highly jointed, and preferably thin-bedded.[5] Permeability in the sense of mass permeability may be unfavorable because that condition could allow water to pass through the entire rock mass rather than to be channeled along restricted pathways.[6] This concentration of flow is necessary for the karstification to take place.

Carbonate terranes occur in each of the four major groundwater regions of the United States as described by Meinzer (1949).[7] Some of the more prominent of each region are described briefly by Stringfield and Le Grand in Hydrology of Carbonate Rock Terranes - A Review.[8]

The Karstlands Map in the National Atlas of the United States further delimits actual karst terranes.[9] The distribution is generally summarized as in Table 4. Alaska and Hawaii have only pseudo-karst areas. Puerto Rico is karstland along the northern coast, west of San Juan.

## Karst of Florida

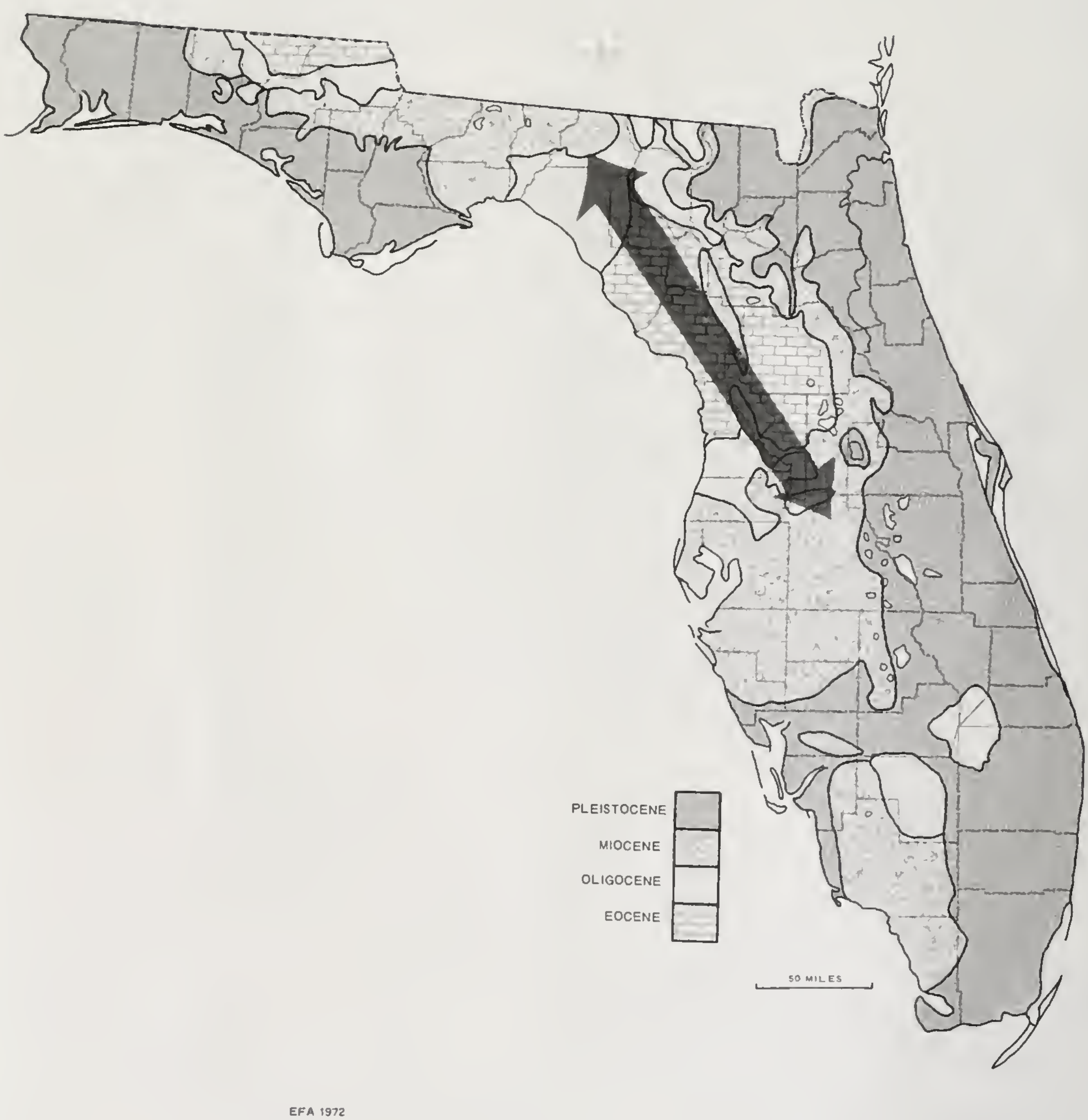
This brief review of world and United States karst serves as background for this study of Florida karst. The physical region of central Florida takes on more importance when its size is compared with that of other karst areas, for it has the largest area of contiguous exposed karst surface in the United States.

Florida is composed of sedimentary layers resting on the continental platform far below the surface. Deposition was carried on through the Cenozoic under shallow seas and then continued intermittently through the Pleistocene Epoch. The peninsula underwent some modification in attitude because of disturbances in the basement rocks during a Post-Oligocene Orogeny. The deformation resulted in uplift of an area of west central Florida and is termed the "Ocala Arch." (See Map 5.) Once-horizontal beds of limestone, clay and sand were domed upward from below as erosion took place to lower the surface from above. The resulting geomorphology of the study area is that of an eroded dome or anticline, with very gentle dips, exposing older rocks at the center and younger strata along the periphery. Thus, rocks of Eocene age are widespread on the surface at the center of the Ocala Arch, whereas the Oligocene is not represented until Live Oak, Florida, is reached to the north, and Brooksville in the south. During the several transgressions and regressions

Table 4 Karst Areas of the United States

| |
|---|
| **Atlantic and Gulf Coast Plain** |
| West-central and central Florida (Ocala Uplift) |
| South-central and east Georgia |
| East-central South Carolina |
| Southeastern North Carolina |
| **East Central** |
| Appalachian Mountains from New England to northern Alabama (The Great Valley) |
| Central Tennessee-Kentucky-southern Indiana |
| Southern Missouri-northern Arkansas (Ozarks) |
| South-central Texas |
| **Great Plains** |
| Southeastern New Mexico |
| **Western Mountains** |
| Northern Arizona (Colorado Plateau) |

# THE OCALA ARCH




**Map 5**

Source: Florida Geological Survey

of the seas, varying portions of the topographic "highs" were left subaerial. This phenomenon complicates the geology, causing unconformities as well as disconformities in the structure of the rocks. Regional terrace deposits or ancient shorelines further influence the physiography.

The study area is centered on the Ocala Uplift; specifically it is the area of outcropping or near-surface, Eocene rocks. The most typical manifestation of this landscape is the limestone plain where the Eocene rocks are only lightly covered with permeable sands. (See Figure 2.) Ranging north-to-south through the limestone plain is the area called the Brooksville Ridge. This ridge is composed of younger deposits of sand and clay overlying the Eocene rocks. Some areas are hilly, probably a result of differential subsidence of underlying materials which had become voided by solution. Other parts of the ridge seem to be sands and dunes remaining from Pleistocene terrace deposits.

In Gilchrist and Levy counties and practically "within" the Brooksville Ridge is the area termed the Waccasassa Flats, partly underlain by a graben developed during the movement of the rocks that formed the Ocala Uplift at the end of Oligocene time.[10] The land features are not flat but are sandy hills underlain by Miocene and Pleistocene clays that retard percolation of water and result in perched lakes and a pocosin type of swamp drainage.

These "higher" areas just described are essentially nonkarst, their surface expression not particularly resulting from solution. Their appearance is distinctly different from that of the karstified lime-

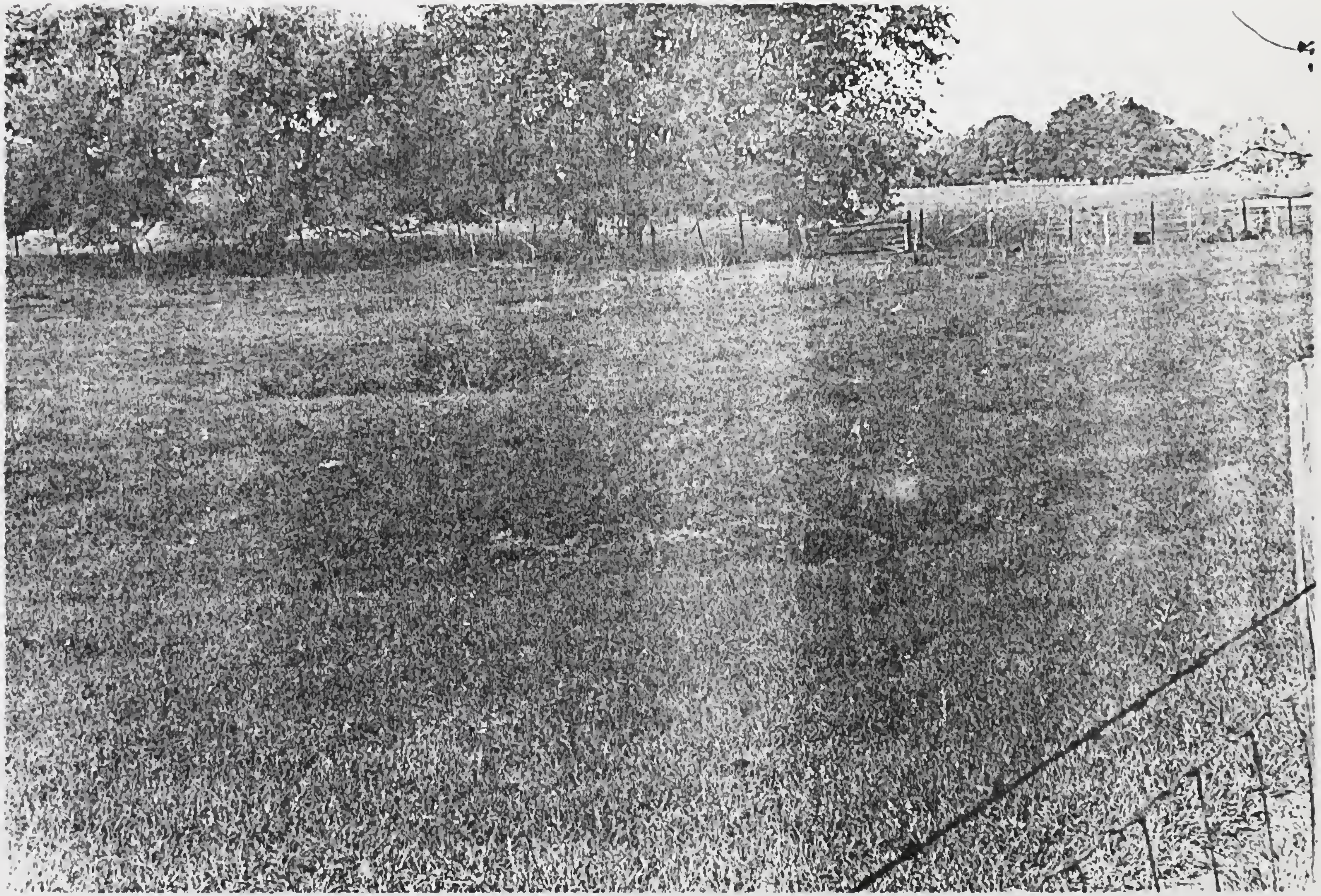


Figure 2 -- Typical Doline-Filled Karst Plain Northeast of Chiefland

stone plains areas to the east and west of the ridge-hill-dune complex. The transition zones are sometimes gradual and both topographic types are seen on a given traverse. More often, however, the borders are abrupt, showing as distinct boundaries, especially on aerial photographs.

On the Gulf coast and in almost all of Dixie County the water table is quite high, presenting a "drowned karst" aspect. This coastal area is not presently considered karst because of the masking of the features by water and shallow surface deposits.

The areas remaining for study are the limestone plains. This area is, in the opinion of the writer, the most distinctive karst in Florida. There is another Eocene outcrop in the Panhandle (or west Florida) near Marianna, but this area is not as extensive as the peninsular outcrop.

## The Eocene Limestone Plains

The limestone plains have been traditionally considered as agricultural areas. The outcrop is divided into two parts by the overlying Waccasassa Flats and the Brooksville Ridge, called Bell Ridge in its most northern extent. Vernon has at different times called portions of the plains by place-names (Chiefland and Williston), but for this research they will be termed The Bell-Trenton-Chiefland Limestone Plain and The Newberry-Williston Limestone Plain. The two areas are quite similar, especially in their origin. There are, however, some differences in the character of the sinkhole topography which are often difficult to interpret.

The most characteristic karst feature here is the doline, a sink or sinkhole with sloping sides found almost continuously in the lime-

stone plains. The landscape is characteristically rolling, with the shallow basins of interior drainage separating low rocky interfluves. The area is not unlike parts of the Pennyroyal of Kentucky in the "lay of the land." Low areas of subdued relief could sometimes fit the definition of polje, or karst plain. Their origin could possibly be tectonic, downfaulted or downfolded. In any case, these expressions are further modified by solution, with lowering by sub-surface solution a factor of considerable importance. Florida poljes lack the steep walls found in some European karst. Generally, the term which might best be applied to Florida karst landscape is "solution-subsidence," descriptive of the formation of the karst plains. The shallow basins are often coalesced, forming compound sinks.

Water percolates downward through the sides and bottoms of the sinks, sometimes flowing rapidly into one of several smaller sinkholes in the floor of the doline. Hardly any water stands or flows on the surface except in scattered areas of clay deposits which are probably residual or reworked Miocene formations. Therefore, there are few sinkhole ponds or karst lakes perched on the limestone plains.

The land has been used mostly for agriculture and some subsequently planted pines, but clumps of hardwood trees remain that are more often than not in deep-sinkhole locations. Farmers have placed boulders from the fields into the sinkholes for so many years that the topographic expression is now virtually an outcrop of limerock rather than a void. These same cherty limerock boulders are sometimes found placed by the farmer along the fence rows.

Scattered throughout the karst plain are vertical-walled sinkholes called cenotes. (See Figure 3.) Origin of the cenote is from the collapse of overlying rocks into a cavity rather than from a lowering of the surface slowly downward by "sagging" or by solution beneath a soil cover. Whereas dolines may be formed either of two ways, the steep-walled cenote is evidently catastrophic in its formation.

Cenotes of large size are readily found in the eastern range of the limestone plain, especially near Newberry. They vary from five or six feet across to as much as fifty feet. They may be connected to one another by underground passages which may be caves or contain water.

An interesting karst feature most prevalent in the western plains, near Chiefland, is the vertical-walled ponor or natural well. (See Figure 4.) These are often perfectly round and are of varying depths, containing water in some cases. They are sometimes closed from the top, appearing to have formed from deeper zones upward. This mysterious closed-top well can be seen when the observer is below ground level, as in an excavation such as an old quarry or highway borrow-pit. The smoothed and rounded wells are seen also as cave chimneys leading upward from cavities, sometimes opening at the surface, sometimes seeming to taper inward to small size, then closing. Most ponors observed are obviously open at the top or they would not be noted in a surface reconnaissance. It is this type of sinkhole, as well as the cenote, that often must be fenced to lessen its hazard to men, animals, and equipment. (See Figure 5.)

Origin and location of the tubes and pipes are most often joint-controlled; and they may run as galleries along bedding planes. The

Figure 3 -- Cenote About Twenty Feet in Diameter (Jerome Sink North of Newberry)

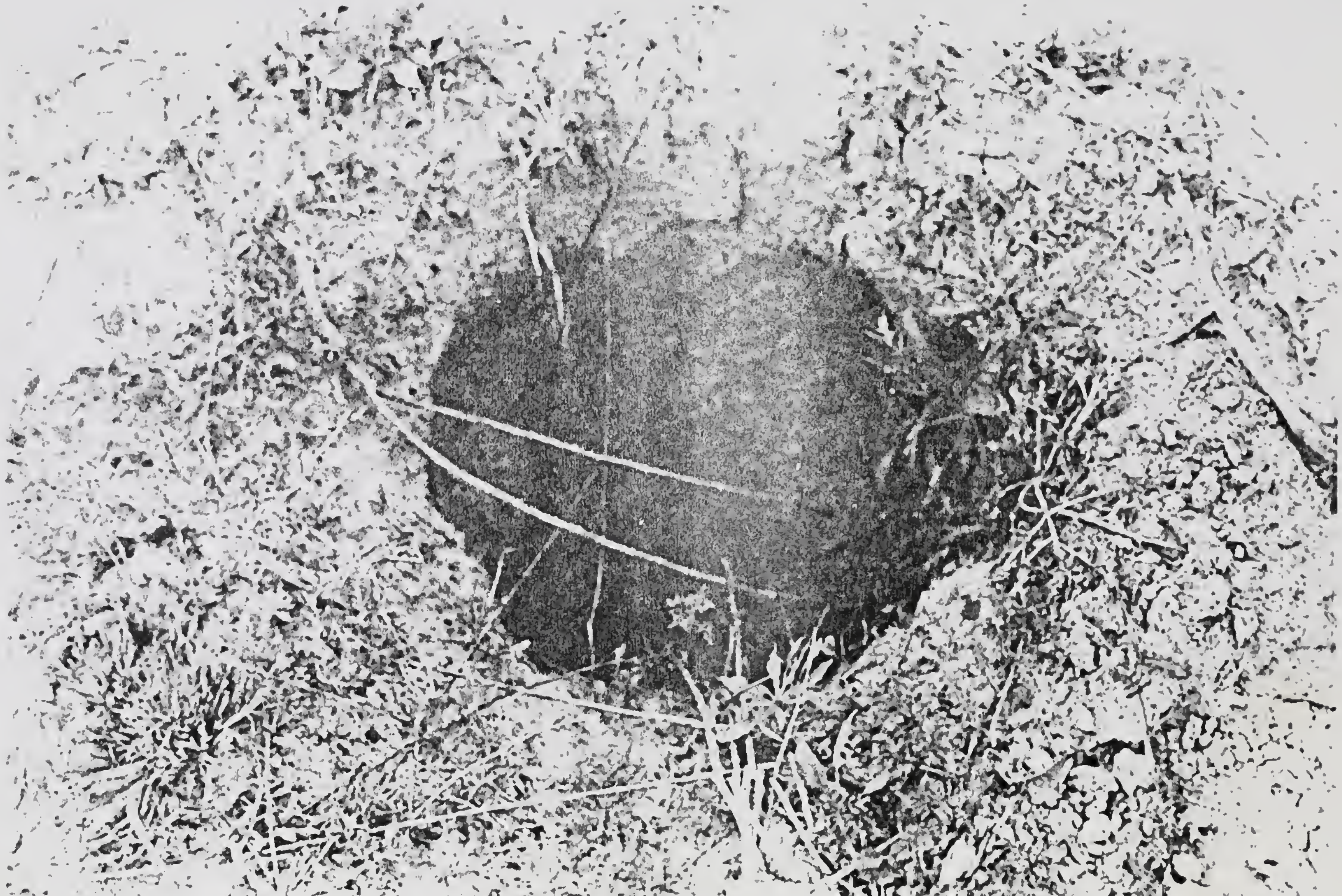


Figure 4 -- Ponor or Natural Well About Two Feet in Diameter (Three Miles North of Newberry)

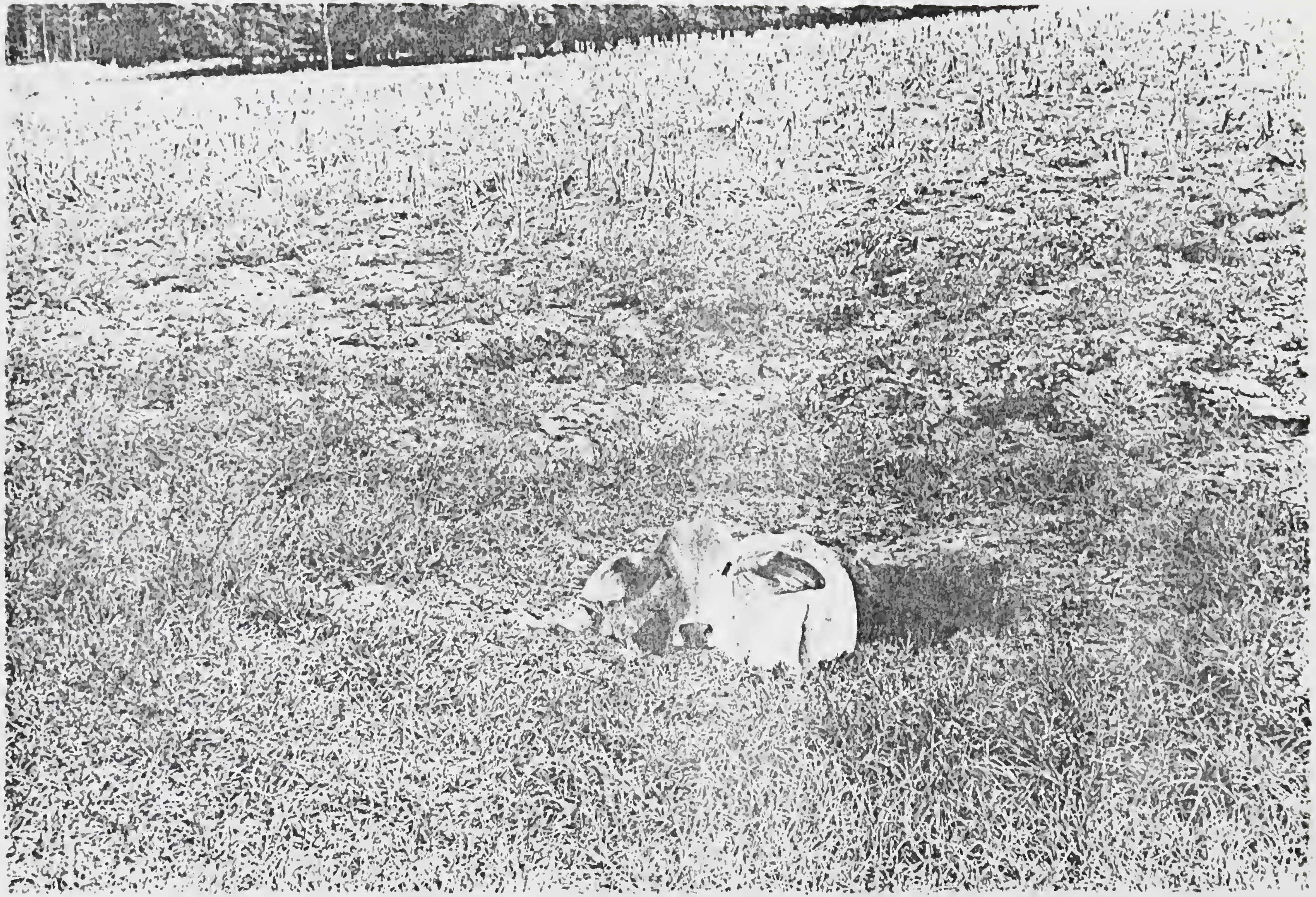


Figure 5 -- Trapped Brahma Calf in Well Sinkhole on Highway 320 East of Chiefland

circular regularity of some wells may be a result of swirling of vadose water downward, or phreatic water upward, expanding under artesian conditions which have existed in the past.[11] The roundness is unusual in that there is a smoothed inner wall, with truncated fossil shells, evidencing a process of corrosion, rather than solution alone.[12]

These vertical wells and also numerous "inclined" or horizontal pipes or tunnels give a honey-combed aspect to a vertical cross-section. (See Figure 6.) It is easily observed that the cavities fill with non-indurated surface materials, sand and clay, which tend to move downward through gravity and movement of water. When this displacement occurs, often after a heavy rain, new holes of all sizes open up. The consensus is that the most "favorable" time is during or immediately following a prolonged heavy rain breaking a long drought.

A karst feature of considerable importance is the ubiquitous outcrop of limerock. (See Figure 7.) The karstification of the limestone plains has left uncovered areas of rock. Often there are boulders present which have been hardened by concretions of silica precipitated into cavities. The unusually hard durable rocks are sometimes piled up to remove them from cultivated fields. They fill sink hole sites or line fences where they are available for use by a crusher operator for aggregate. Limestone only sparsely covered with soil and grass can be seen in the ditches beside the highways, especially Highway 41 between High Springs and Williston.

The rather poor, excessively drained soils of the limestone plain are often several feet thick on the irregular surface of the underlying

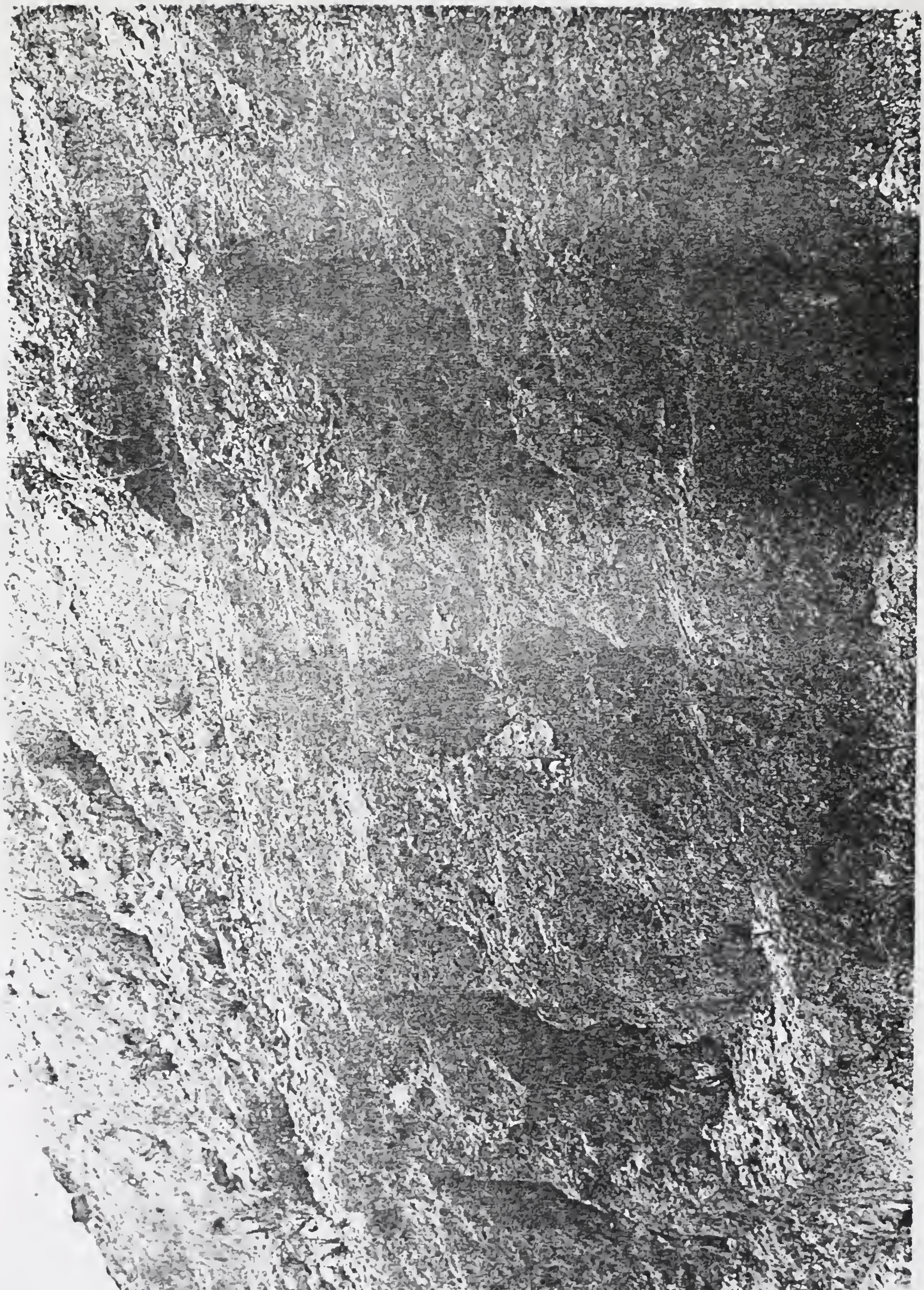


Figure 6 -- Borrow Pit Wall, Good Vertical Cross Section of Karsification on Giglia Farm Near Chiefland

Figure 7 -- Outcrop of Surface Limestone in Plowed Field Three Miles West of Gainesville

rocks, yet outcrops are frequent. An unusual occurrence in the study area is a deposit of "bog iron" ore outcropping in northern Levy County. The ore is a high-grade limonite possibly deposited in the limerock by rising artesian waters carrying iron dissolved from Lower Eocene strata.[13] The ore is reddish-brown in color and stains the fields and sandy roads for several miles. One quarter of a quarter-section is so rocky that nearby residents refer to it as "The Iron Forty." (See Figure 8.)

The karst of Florida as a whole is not typified by the Eocene outcrop area. There is in fact an almost infinite variety of expression. Areas beyond the Eocene outcrop are influenced geomorphologically by the Eocene levels. These underlie younger formations flanking the Ocala Uplift. The beds serve as the principal aquifer of Florida. Solution cavities in this rock sometimes result in the differential subsidence of overlying formations to create hills or lake basins. There is said to be a rough ratio between the thickness of the overburden and the size of a sinkhole collapsed or sagged to fill a void below. The sinkholes at Gainesville or to the east in the Hawthorne deposits would therefore be large and spaced well apart. Those in the limestone plains with almost no overburden are often quite small and closely spaced. Soil or cover must be considered too because case studies show that even though holes may occur under sandy soil, they fill rapidly again and are usually not reported as significant.

Most of the Florida lakes and prairies could be called karst features because they owe their origin to a lowering of the surface by the solution of underlying rocks. The shallow prairie lakes sur-

Figure 8 -- The Iron Forty, Acreage Northeast of Chiefland Showing Iron Ore Outcrops

rounding the study area are lined with fine grained sediments making the limestone impermeable. When hydrostatic pressure builds up, these prairie lakes "break through" and drain into an adjoining sinkhole.

The preceding sections have involved a formal description of karst as a complex of landforms. Next followed the identification of the more important karst areas of the world and of the United States, ending with an expanded outline of karst in all of Florida. With the foregoing to serve as a frame of reference, the focus of the present research is reached. Its raison d'etre is the description and explanation of the Eocene karst features as they affect land use in this selected region of Florida.

NOTES TO CHAPTER II

[1]Allyn C. Swinnerton, Hydrology of Limestone Terranes, Physics of the Earth IX, Meinzer, ed. (New York: McGraw-Hill Book Co., Inc., 1942), p. 656.

[2]C. A. Cotton, "Limestone Landscapes," Landscape (Cambridge: University Press, 1941), p. 281.

[3]V. T. Stringfield and H. E. Le Grand, Hydrogeology of Limestone Terranes in the Coastal Plain of the Southeastern United States, Geological Society of America Special Paper No. 93 (1966), p. 351.

[4]William D. Thornbury, Principles of Geomorphology (New York: Wiley and Sons, Inc., 1969), p. 304.

[5]Ibid.

[6]Ibid.

[7]O. E. Meinzer, Ground Water, Physics of the Earth IX, Meinzer, ed. (New York: McGraw-Hill Book Co., Inc., 1949), p. 162.

[8]V. T. Stringfield and H. E. Le Grand, Hydrology of Carbonate Rock Terranes--A Review, Journal of Hydrology, Vol. 8, No. 3 (1969), p. 368.

[9]United States Department of the Interior, Geological Survey, National Atlas of the United States of America (Washington, D. C., 1970), p. 77.

[10]William J. Yon, Jr., and Harbans S. Puri, "Geology of the Waccasassa Flats, Gilchrist County, Florida," Bulletin of the American Association of Petroleum Geologists, Vol. 46, No. 5 (1962), p. 674.

[11] Robert O. Vernon, Geology of Citrus and Levy Counties, Florida, Florida State Geological Survey Bulletin No. 33 (1951), p. 41.

[12] Harbans S. Puri, J. William Yon, Jr., and R. Oglesby Woodson, Geology of Dixie and Gilchrist Counties, Florida, Florida State Geological Survey Bulletin No. 49 (1967), p. 33.

[13] Vernon, Geology of Citrus and Levy Counties, p. 286.

# CHAPTER III

# METHODS, TECHNIQUES, AND TOPICS EMPLOYED IN KARST AREA STUDIES

The focus of the study, as indicated before, is upon the limestone plains, termed for geographic reference, Bell-Trenton-Chiefland and Newberry-Williston.

## Methods

In the literature reviewed in the background chapter, the scientists have used several methods and numerous techniques for research. The formal statistical method is best demonstrated by Placido La Valle in his study of Kentucky sinkholes.[1] In an area of 800 square miles in South Central Kentucky, using USGS quadrangle maps, La Valle carried out detailed studies on a random sample of 25 percent chosen from an arbitrarily placed grid. His measurements constituted the basis for a morphometric analysis of linear karst development. This examination revealed two facets reflecting linear trends: the depression elongation ratio and the relative orientation of the depression axes. His results show that major axes parallel joint strikes and that spatial distributions correlate with structural weaknesses such as numerous joints and thin bedding planes. Studies have been made which confirm that this condition also exists in the Florida karst, but the results are not based on formal statistical methodology.

The experimental method is one in which data are secured under conditions in which some forces are held fairly constant while other forces are measured. In the literature surveyed, the best example of this research method is described by Clifford A. Kaye in "The Effect of Solvent Motion on Limestone Solution" (1957).[2] He performed actual experiments with blocks of limestone, water, and acid solutions. His demonstration proved that agitation and motion of solvent flow are positive factors of importance in limestone solution patterns. From the principle that the greater the flow velocity, the greater the rate of solution, he suggests that differential solution in proportion to velocity takes place and that this process causes preferential conduit enlargements of cavities by phreatic waters.

Few actual experiments exist as to degrees and patterns of solubility of Florida limestone. Engineering studies have been made concerning relative strengths of wet and dry limerock, but controlled experiments are only infrequently described in the literature. C. V. Dolliver conducted several physical projects in the laboratory for her thesis "The Geomorphology of the West-Central Florida Peninsula."[3] These are not exclusively performed on limestone rocks, however, but involve deposition and arrangement of materials by moving water in the Gulf Limestone Plain area. H. K. Brooks has performed a large number of laboratory experiments to analyze the chemical composition of surface and ground waters throughout the karst area of northern peninsular Florida.[4] His quantitative results are interesting in that they show

the overall rate of solution in the karst terrane as about 1.5 inches per 1,000 years. These figures were based upon field samples of water collected and analyzed in 1967 and show that the lowering of the regional landscape takes place at a rate only a little less rapid than that calculated by Sellards in 1908.[5]

The general research method of analogy has been used rather broadly in research on limestone terranes. The efforts of scholars to make comparisons and to attribute certain characteristics of one karst area to those of another are frequent. They are not applied without reservation, however, because the karst landscape varies so extremely with physical exigencies. The effort to synthesize a karst vocabulary is one way to emphasize the analogies that do exist. Florida karst is rarely compared to that of other areas. The gentleness of dip, the high water table, and the subtropical climate combine with the structural characteristics, dense and highly jointed, to present a unique landscape. Tropical karst has been researched by Sweeting,[6] Meyerhoff,[7] Monroe,[8] and others, but only Corbel[9] has actually made comparisons of another landscape and the Florida karst. His description of features in Mexico mentions similarities and contrasts between Yucatecan and Floridian terranes.

The present study will employ two methods other than the historical method already being utilized. These are the informal statistical method and the case study method. The informal statistical method is offered as an alternative to the formal when the available data are discontinuous or otherwise unsuitable for formal quantitative handling.

The writer considers that the counting of sinkholes using various techniques is a problem-oriented approach, but the statements obtained from analysis of the Conservation Needs Inventory data are somewhat more formalistic in presentation.

The case study method has been used most often in the literature specifically about karst terranes. As cited before, Sauer and Goodwin both used the Pennyroyal of Kentucky as their case in point. In addition, Dicken and Brown have been especially erudite in their presentation of a case study describing erosion problems of Kentucky "limestone soils."[10] Central Tennessee is another case area covered in Limestone Hydrology in the Upper Stones River Basin by Moore, Burchett, and Bingham.[11] Florida karst has been specifically investigated by several students of the area in case study approaches. Abbott (1971) in "Twenty Springs of the Oklawaha" describes springs as karst features of a particular area.[12] Lipchinsky in "A Study of the Origin of Limestone Caverns in Florida" offers detailed descriptions and explanations of features found in fifteen Florida caves.[13] O. W. Girard, Jr.,[14] and J. D. Vormelker[15] describe the geology of the High Springs Quadrangle and that of the Gainesville West Quadrangle, respectively. These two studies describe lands which are fairly representative of local karst terranes, as is the underground Santa Fe River chosen for research by R. T. Skirven.[16] All these projects skirt the present study area of the limestone plains, except one conducted by H. K. Brooks, before cited. His topic circumscribes the entire area in a systematic approach which is geological in content. The geographical purview, thus, has been left for the present study.

## Techniques

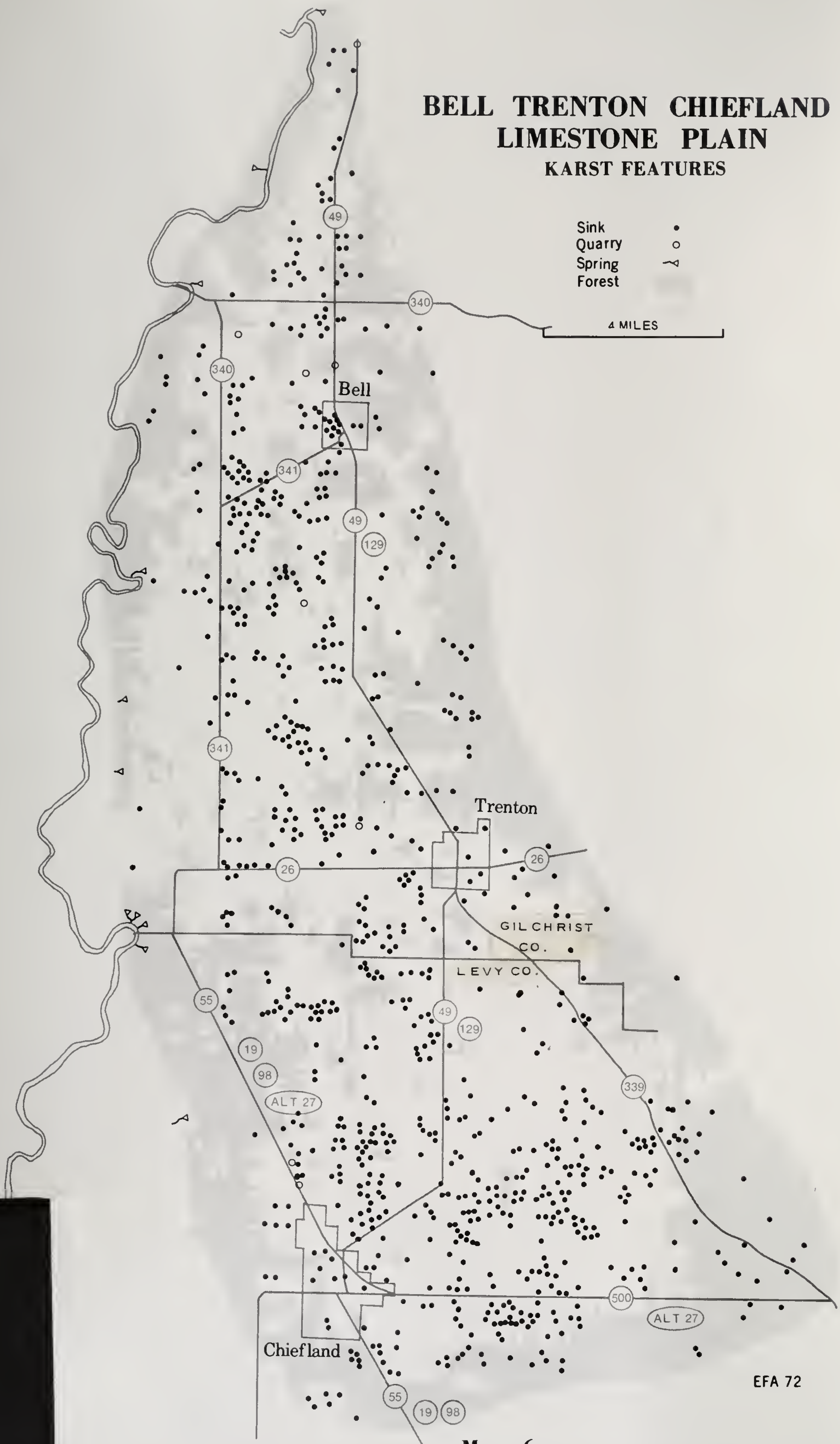
The methods reviewed include the five classic ways of presenting research: the formal statistical method, the informal statistical method, the experimental method, the analogy and the case study. Many techniques or skills have been employed in the use of the research methods reviewed here. The field techniques are generally reconnaissance, measurement, gathering of samples, photography, and map and photo interpretation. The interview has been little used or is unreported, very likely because it is often considered vague or unscientific in approach. All the above mentioned techniques are used in the present research, except for the collection and analysis of samples in the laboratory. Especial attention is called to photography, a tool which can be used to help greatly in the description of the limestone terrane. (See Figure 8.) Almost all available research into Florida topics includes air and ground photographs.

The technique of remote sensing of the environment is comparatively new for limestone research, dating from 1940, or about thirty years. Earliest photos used for this paper are the Agricultural Stabilization and Conservation Service contact prints in stereo coverage of the two counties of the western portion of the limestone plains, Gilchrist and Levy Counties. The sample area, only part of the plain, was chosen for study as an example of an agricultural area, defined as such on Marschner's Land Use Map of Florida. Stereo pairs were examined carefully for evidence of existence of sinkholes, quarries, and springs. Outcrop could not be distinguished. The forested and nonforested areas

are fairly easily discerned on the photos. The result of painstaking marking of sinkholes large enough to show up on the pictures is that the pattern on the land as well as the density of such sinkholes can be calculated. (See Map 6.)

Extremely sophisticated techniques have been reported recently in determining areas which may be "sinkhole-prone." Thermal infra-red imagery and interpretation have led to possibly extravagant claims that collapse-prone areas can be predicted or detected by analysis of data. Coker, Marshall and Thompson worked with multispectral imagery to show that some oval patterns on the recognition maps delineated subsidence areas near Bartow, Florida.[17] J. W. Stewart came somewhat closer geographically to the Eocene limestone plains in his remote sensing report on lakes in west central Florida.[18] He used imagery-producing remote sensors (1) to determine interrelationships between lakes of different characteristics; (2) to develop a classification of the lake shore features; and (3) to establish a classification of lakes in a karst topography. Most of these goals are also sought after here in the present research effort, but through use of conventional photography and techniques of interpretation.

Other reports on remote sensing experiments have not proved that use of thermal infra-red imagery is much more effective than use of stereo pairs. Some features, especially rock outcrops and wet areas, may be detected more accurately by the use of the expensive and sophisticated techniques, but sinkholes in general are discernible to about the same degree with either type of imagery. The hydrobiological in-


BELL TRENTON CHIEFLAND
LIMESTONE PLAIN
KARST FEATURES
Sink
Quarry
Spring
Forest
4 MILES
Bell
Trenton
Chiefland
GILCHRIST CO.
LEVY CO.
49
340
341
129
26
55
19
98
ALT 27
339
500
EFA 72

Map 6

vestigations of lakes, the Everglades, selected coastal areas, the Oklawaha Valley, and muck deposits now being conducted will prove the value of modern techniques for analyses of karst-influenced topography. The rapid drainage prevailing in the limestone plains themselves is probably the factor rendering aerial photographs almost as effective as multispectral reflections.

## Topical Approach

The methods and techniques used for research serve to facilitate the accomplishment of certain tasks and the attainment of selected goals. Another matter of choice is the form of presentation of the results of the work. The topical approach is used here because of the geographical nature of the research. The emphasis, after the background setting, is upon man and his use of the land.

The limestone plains are traditionally agricultural in use. Crops have been grown and livestock tended on this land through the years. "The Effect of Karst Topography on Agricultural Land Use" will be the topic reviewed initially. Also included is the contrasting position-that of examining the effect that man's use has had on the condition of the land. This first topic is treated in Chapter IV, the theme of the present research project, because of the fact that agriculture is the dominant land use in the area.

The second topic is "Hazards Associated with Karst." Three divisions of Chapter V seem logical in the examination of assembled data: the place of sinkhole hazard in contemporary geographical re-

search regarding hazardousness of location or place; the history and status of sinkhole insurance; and the Department of Transportation problems with highway and right-of-way subsidence.

The third subject to be presented is a view of "Limestone as a Resource," Chapter Six. Historically, the presence of minerals has helped in some ways to settle the area and to establish the transportation routes, chiefly roads and railroads. Limerock, dolomite and phosphate are the three outstanding minerals in the case of the Eocene outcrop region.

The last topic to be discussed, as Chapter Seven, concerns "Land Values and Karst." Booming prosperity and increasing demands for land in Florida put new values upon some almost abandoned tracts of rural land. The advantage gained by the presence of karst features, lakes in this instance, is explored in an analysis of the enhancement of land values when these features are present and able to be exploited.

These four topics offer a geographic presentation in the study of karst topography not before attempted. The topical approach emphasizes the use of the land by man and his works.

## NOTES TO CHAPTER III

[1]Placido La Valle, "Some Aspects of Linear Karst Depression Development in South Central Kentucky," Annals of the Association of American Geographers, Vol. 57, No. 1 (1967), p. 59.

[2]Clifford A. Kaye, "The Effect of Solvent Motion on Limestone Solution," Journal of Geology, Vol. 65, No. 1 (January, 1957), p. 35.

[3]Claire Vincent Dolliver, "The Geomorphology of the West-Central Florida Peninsula" (University of Florida Thesis, 1965), p. 37.

[4]H. K. Brooks, Rate of Solution of Limestone in the Karst Terranes of Florida (Florida Water Resources Research Center, Publication No. 6, 1967), p. 1.

[5]E. H. Sellards, Underground Water Supply of Central Florida, Florida State Geological Survey (1908), p. 48.

[6]M. M. Sweeting, Hydrogeological Observations in Parts of the White Limestone Areas in Jamaica (Kingston: Geological Survey, 1955).

[7]Howard A. Meyerhoff, "The Texture of Karst Topography in Cuba and Puerto Rico," Journal of Geomorphology 1-2 (1938-9).

[8]Watson H. Monroe, "The Karst Features of Northern Puerto Rico," National Speleological Society Bulletin, Vol. 30, No. 3 (1968).

[9]J. Corbel, Notes sur les Karsts Tropicaux. Revue de Geographie de Lyon XXX, 1 Lyon (1955). Cited by H. Lehmann in Report of the International Geographical Union Commission on Karst Phenomena (1956), p. 5.

[10] S. N. Dicken and H. B. Broun, Jr., "Soil Erosion in the Karst Lands of Kentucky," United States Department of Agriculture Circular No. 490 (1938).

[11] Gerald K. Moore, Charles R. Burchett, Roy H. Bingham, Limestone Hydrology in the Upper Stones River Basin, Central Tennessee, State of Tennessee Department of Conservation, Division of Water Resources (1969),pp. 8-9.

[12] Elizabeth F.Abbott, "Twenty Springs of the Oklawaha" (Gainesville: Florida Defenders of the Environment, 1971).

[13] Zelek Lawrence Lipchinsky, "A Study of the Origin of Limestone Caverns in Florida" (University of Florida Thesis, 1963).

[14] Oswald W. Girard, Jr., "The Geology of the Gainesville West Quadrangle, Alachua County, Florida" (University of Florida Thesis, 1962).

[15] Joel David Vormelker, "Geology of the High Springs Quadrangle, Florida" (University of Florida Thesis, 1966).

[16] Raymond Taylor Skirven, "The Underground Course of the Santa Fe River Near High Springs, Florida" (University of Florida Thesis, 1962).

[17] A. E. Coker, R. Marshall, and N. S. Thompson,"Application of Computer Processed Multispectral Data to the Discrimination of Land Collapse (Sinkhole) Prone Areas in Florida" (1969).

[18] Joseph W. Stewart, "Synoptic Remote-Sensing Survey of Lakes in West-Central Florida" (1969).

# CHAPTER IV

# THE EFFECT OF KARST TOPOGRAPHY ON AGRICULTURAL LAND USE

## Historical Perspective

Patterns of agriculture are necessarily determined by both physical and cultural influences. One or the other may be dominant, but both must be considered in a geographic appraisal. They physical landscape provides the setting for the complex interactions of man's influences through time. Therefore, changes through historical time are important in explaining present patterns of land use.

The study area is fairly homogeneous climatically because of the rather small size of the region. There are differences in types of landforms, however, as described in Chapter II. These geomorphological variations have pre-determined the soil types which, therefore, are mostly azonal (influenced principally by factors other than climate). Parent material of limestone, sand, silt, and clay underlie the soils and, along with drainage conditions, are responsible for their characteristics.

The distribution of natural vegetation as it existed almost continuously over the land also was not strongly influenced by climate (see Map 7). Patterns of vegetation responded to soils, which are principally related to geology. Vegetative cover or physical appearance of the landscape helped early settlers make decisions about how to use the land initially.

Settlement of the study area took place slowly and the people lived on the land, farming only the better soil areas. Early farming was mainly of a subsistence type, for markets were remote. Corn, rice, sugar cane, and sweet potatoes were grown, and stock raising was also important. The growing of sea-island cotton became popular, especially following The War years (1861-1865) and much hammock land was cleared for cotton.

Alachua and Marion Counties were settled first, and substantial planters were included among the first Americans in that area. Alachua County was settled in the 1820's and 1830's (in the eastern and southern sections of the present county); Marion County was settled in the 1830's and early 1840's, despite the fighting during the Second Seminole War which took place near Ocala.[1] In both these counties, agricultural staples were produced early, along with the plantation economy based on slave labor, but this settlement mainly involved richer hammock lands east of the Eocene outcrop area.

In the sparsely settled county to the west in central Florida, lonely farmsteads of the successful land claimants grew patches of corn and beans, cane and tobacco among stumps of cleared and burned land. The first town mentioned in the area by Cash is Archer, settled in 1859, coincident with the building of the Florida railroad through the section.[2]

Practically all the countryside was open range for livestock. Cattle and hogs were fairly well fed on pasture grasses in the prairie lands and oak mast in the hammocks.[3] Stock raising was the total occupation for some of the population because prairie land unsuited for cropland often made good pasturage.[4]

In the southern parts of the study area, citrus became important, beginning in 1859 with a single orange grove at Micanopy.[5] Soil and climate were suitable for oranges and the industry expanded, increasing land values appreciably. With the discovery of phosphate, the area boomed even more, and land speculation followed. Towns were laid out and many lots surveyed, but not all were settled, as is typical of American land booms. There was a general depression following the collapse of the boom. Prosperity had not yet completely returned when the great freeze of 1894-1895 killed all the orange trees in the area. Prior to the freeze, almost every farm in the southern area had its own orange grove. With citrus and stock raising as primary ventures, not much land was farmed except for subsistence crops. Turpentining became profitable and the industry grew rather rapidly, sometimes competing with logging operations for the pine trees.

The start of commercial forestry first provided a source of supplemental income for subsistence farmers but was conducted on rather a small scale in the karst areas because of the lack of waterways. In northern Florida only the timber tracts convenient to the ports of Pensacola, St. Marks, or Jacksonville were extensively logged off before 1900.[6] So the years of early settlement did not drastically change the appearance of the forests of the study area.

Truck farming was greatly extended after the freeze and was fostered by the extension of the railroads into the region. Cantaloupes and watermelons, as well as peppers and some eggplants, were the principal vegetable crops then as now.[7] In the areas of hard rock phosphate

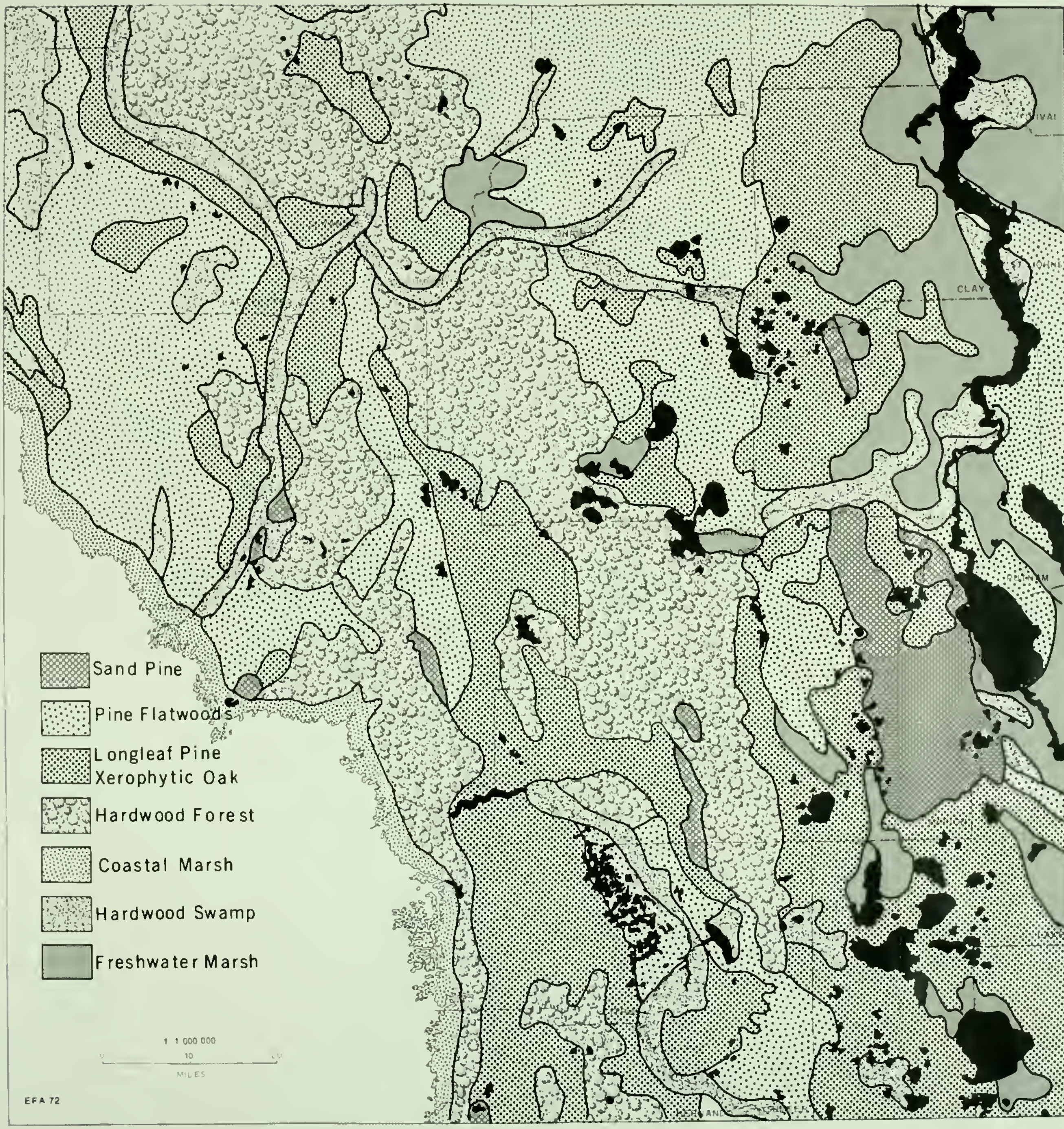
mining, on the other hand, hardly any attention was given to agriculture, although much of the forest was being cut over to provide fuel for drying operations. By the second decade of this century, the growing of truck crops and corn was following some clearly recognized practices. Vegetables, such as tomatoes, snapbeans, and cabbages, were planted very early in the growing season and fertilized heavily. Then a corn crop was put in the same field to take advantage of the remaining fertilizer in the soil. This provided a rotation program of sorts with good yields.[8]

Although a little tobacco had been grown and sometimes sold by the pioneer settlers, six acres of bright-leaf tobacco in the Suwannee River Valley, in 1921, marked the first commercial venture in the area.[9] In 1923 some 200 acres were harvested, giving tobacco growing importance as a money maker.[10]

The most active lumbering took place in the late 1920's and early 1930's.[11] Whereas before only small local sawmills had used logs for local construction, now large companies ravaged the land, removing chiefly the longleaf pine. Small gauge railroads and primitive logging roads criss-crossed many areas, along with a few farm roads utilized by farmers who came in and began clearing the brushy cut-over lands for cropland.

The choice of specific uses for land in farms was made by the grower, mostly in response to soil type, indicated to him by the native vegetation (see Map 7). It is apparent that there is a definite relationship between the patterns of soils and the details of the geology in the area. The main features of the geology have been summarized in Chapter II, and it is shown that limestone now exposed at the surface once was covered with

# NATURAL VEGETATION




Map 7

SOURCE: Davis, General map of Natural Vegetation of Florida, 1967

younger strata of clay and sand of which remnants remain on the uplands. Over all is the mantle of residual material which is the matrix for the formation of the soils. The native vegetation type is frequently utilized to distinguish soil areas, even after the removal of the virgin growth. Residents of the study area commonly use the terms "pine land," "hammock land," or "prairie land," as names for subregions. This nomenclature is employed here to emphasize man's position and view of the physical matrix of his environment. For instance, in the vernacular, a farmer comments "I have most of my 'prairie land' in pasture." Thus the geographic subregions are discussed here as land types rather than by geology, soils, vegetation, and land use separately. As a geographer, this writer emphasizes man's perception of and interaction with his environment; therefore the vegetative terms for land types are used here, in preference to the complex spectrum of soil variations.

## Pine Land

The chief natural growth in the study area once was the longleaf pine; these lands were referred to as either "rolling pine lands," or "flatwoods." The rolling pine lands are slightly undulating, well-drained lands and can be subdivided into: "open pine," "pine with blackjack undergrowth," and "pine with turkey oak undergrowth." The open pine areas with tall longleaf pines are almost completely gone today, and much of this land is now cropland, pastures, or planted pines (see Figure 9). Blackjack oak (*Quercus marilandicus* Muench.) still abounds in the driest or most barren areas and the turkey oak (*Quercus laevis* Walt.) predominates

Figure 9 -- Planted Pine Replacing Original Longleaf Pines (East of Newberry)

on soils a little finer (see Figure 10). The soil in the rolling pine lands is mostly thick sand with minor components of silts and clays. The hills overlie an uneven limestone surface with scattered large sink-holes. Small outcrops of flinty limestone are present in the soils and humus is sparse or entirely lacking because of repeated fires. The gopher mouse or "salamander," as it is called by the native Floridians, burrows into the sandy dry soils, leaving low mounds a foot or more in diameter. Not only does this help to mix the soil, but also encourages young pine seedlings to get a better start in the fresh mound. The bare sand also offers the very young tree some protection from fire. When the tree is older it withstands ground fires well, and most mature trees are blackened at some time or other during their growth.

Hammock Land

"Hammock" as a vegetative term is applied to areas where the timber growth is dense enough to result in the accumulation of leaf mold on the surface.[12] There is a wide variation of vegetation types and plant groups in the makeup of different hammocks, owing to the variables of soil and drainage conditions. Those having the poorer, sandy soils will have a higher percentage of pines than those with richer soils. The richest soils of all will have large stands of fine hardwoods and associated flora, which give the hammocks their wide appeal to farmer and naturalist alike (see Figure 11).

Within the hammocks there is competition for dominance among the hardwoods, and between the hardwoods and pines. Pines do not tolerate the crowding which results from good growth on nutritious soils, and

Figure 10 -- The Writer Observing a Stand of Oak Trees in Western Marion County

Figure 11 -- Hammock Land With Sinkhole Lakes on Bellamy Road in Northern Alachua County

hardwoods do not tolerate the fires to which pines are resistant. Fires across the land have always controlled the landscape in Florida, and pines quickly replace hardwoods which have been burned out. Rocky outcrops or wet sink areas offer some fire protection to forest cover. Hardwood hammocks will slowly accumulate leaf mold around their boundaries by the steady dropping of leaves in these sub-tropical conditions and thus, by soil enrichment, slowly invade the surrounding pinelands.

The sandy soils of most hammocks are internally well-drained, with frequent limestone sinks and sinkholes. Rainfall finds its way to the sink areas, where almost no surface streams exist. Where hammocks have been cleared off for cultivation, the surface soil varies from light brownish-gray, to pale brown, to yellowish gray.[13] The depth to limestone may vary greatly from a few inches to many feet. Most of these soils are planted to corn and peanuts, with considerable tobacco and watermelon acreage as well. Even though the area soils are not especially suitable for corn, it is grown extensively because of hog-raising needs.

Prairie Land

This designation in Florida is a specialized use of the term "prairie," being applied by the early settlers to lands affected by freshwater inundation. The numerous lakes and ponds of the study are are all shallow with nearly flat shores. The shorelines are subject to wide fluctuation with the rainy cycles, sometimes being inundated, sometimes exposed. Such areas, as well as the silted-in beds of former lakes, are termed prairie land.[14] The beds of former lakes represent either advanced stages

of eutrophication, or lakes whose sealed-in bottoms have become punctured by natural causes, allowing the waters to drain away into the underlying limestone. The huge Payne's Prairie in Alachua County is a well-known example of such a karst lake which entered a downdrawn cycle in recent historical times, to become grazing land.

The soil of these lake margins and other prairies in the study area varies from rather sterile sand to peaty sand mixtures and occasional silicified limestone. The vegetation in the deeper and more permanent pools is entirely aquatic, whereas the outer pond margins can support a few small trees and shrubs, and while these two vegetation types are very different, there are all gradations in between. All treeless areas, permanently or periodically inundated, are therefore included under the designation of prairie lands.[15] To this writer, they represent one of the more distinctive features separating Florida's from other karst terranes.

## General Land Use Patterns

Land use in the study region has always undergone some changes, but agricultural areas have remained fairly definite in location. The first land use map of the entire United States was made by F. J. Marschner, an agricultural economist with the Bureau of Land Economics,[16] during the period from 1945 to 1950. The compilation scale was 1:1,000,000 with a map prepared for most states at that scale. The final more generalized map was published in 1950 at a scale of 1:5,000,000. For the National Atlas of the United States published in 1971, J. R. Anderson revised the original Marschner map for publication at a scale of 1:7,500,000. He

mainly used aerial photography (mosaics of contact prints), as well as some statistical and other surveys to make decisions about land uses for each state* (see Map 8). The study area for west central Florida is delineated as combinations of Cropland, Forest Land, or Grazing Land, by letters C, F, and G— the order and case signifying the relative importance of dominant uses. The study area is chiefly designated as Cgf on the limestone plains, which means that cropland is the dominant land use in the Bell-Trenton-Chiefland area with grazing and forest land as secondary uses. "F" appears most frequently around the periphery, sometimes in combination with "s" meaning swamp. The two lobes of the limestone plain can be seen distinctly; especially well defined is the Bell-Trenton-Chiefland extent. This localization of land uses corresponds to areas similarly delimited on both vegetation and soil maps. Soil associations are dependent upon geology; natural vegetation is governed by soils; land use patterns seem to overlie vegetation tracts.

When agricultural areas were chosen for more intensive study of the impact of karst features, Marschner's areas marked as cropland (in combination with other uses) were used as a base for sampling and case studies. From the natural growth, the hammock lands most often yield to crops; wet prairie land, even within agricultural regions, is little changed; but pine land, depending on economic conditions, has often been farmed.

The effect of the limestone topography on agriculture can also be seen, though not so dramatically, in examination of individual farmscapes. On the case study farms, size and arrangement of fields sometimes indicate

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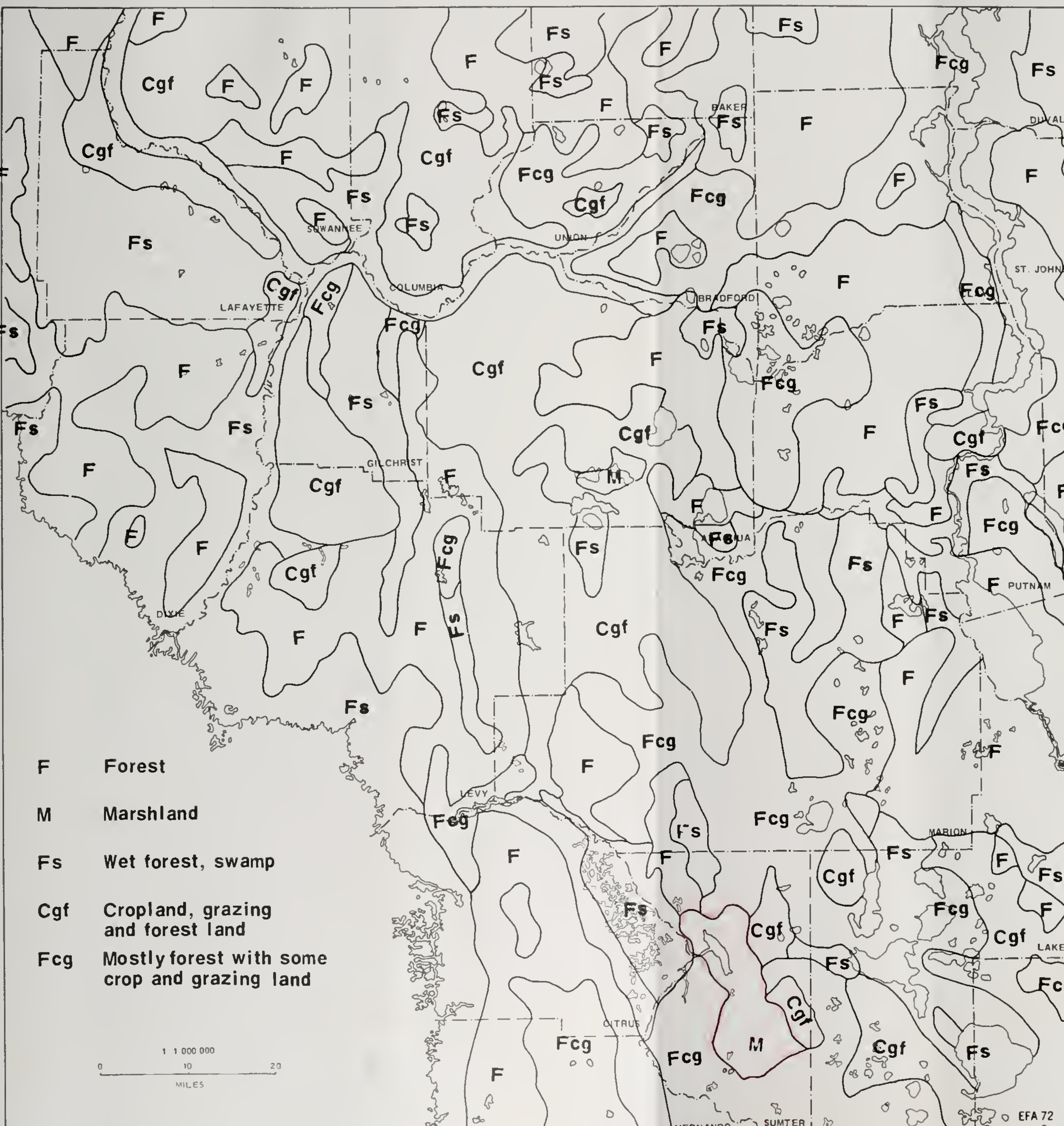
*James R. Anderson, Chief Geographer, United States Geological Survey.

## MARSCHNER'S LAND USE




Map 8

Source: Marschner's Land Use Map of Florida scale 1:500,000.

presence of karst features. Dividing lines or field boundaries may follow lines of sinkholes, adding an unwelcome problem of fencing to that of sinks and erosion (see Figure 12).

The effect of the karst terrane on agriculture is that it is a limiting factor on man's use of the land. Less freedom of choice at everyturn is offered the farmer. The original choice for specific use for subsistence, and later the response to economic factors, are always influenced by the "lay of the land." In the karst terrane of the study area, agriculture is practiced on the limestone plains despite the limits and hazards of the landscape.

The pale sandy soils are of variable thickness and have been subject locally to severe wind erosion. They are excessively well-drained (xeric) because of the permeability of the underlying limestone, and when left without cover, they can become severely eroded by wind. After the land was cut over for lumber and subsequently cropped, the problem of blowing in the 1930's was so drastic in local areas that the area between High Springs and Newberry was compared to the dust bowl of the Great Plains.[17] The problem was somewhat alleviated by the introduction of Pensacola Bahia grass in the late 1940's.[18] Other solutions were tried also, such as windbreaks of planted pines along highways and fence rows. The strips of gree are an attractive addition to the landscape today.

In the whole of the study area the proportion of land in cropland, forests, and pasture is approximately 3:3:2. Soil Conservation Service samples chosen in agricultural lands in 1966 showed 37,36, and 23 percent, respectively.[19] Forests predominate in Dixie County and coastal areas as

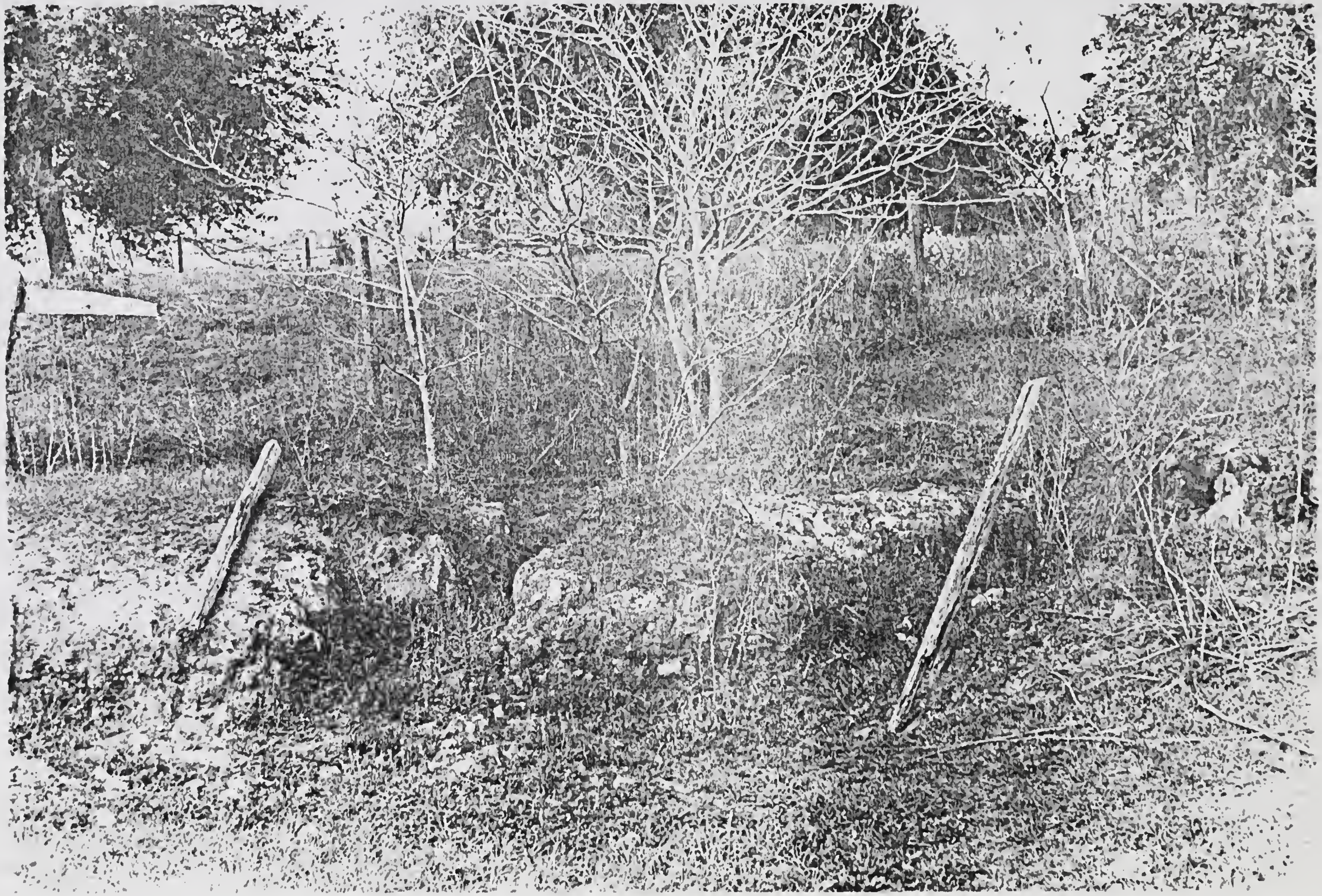


Figure 12 -- Erosion Around Sinkholes, Hazard to Fences on Highway 320 East of Chiefland

well as in the river valleys and pocosin swamps. Cropland predominates in the limestone plains, but both planted pines and improved pasture are becoming increasingly important. Chief crops vary through the area generally, with tobacco bringing in more money and using less land than other crops. The allotment system keeps the acreage small, but the yields are high because of the intensive methods employed. Soil areas unmarked by sinkholes or outcrops are chosen for tobacco, and irrigation is extensively employed. Peanuts are important especially in Levy County and are grown scientifically in the sandy soils of former pine lands. Corn is ubiquitous and is mostly used for feed. Sweet corn, melons, and vegetables are grown anywhere in the area. Citrus is important in the southernmost counties of the study area—Citrus, Sumter, and Marion. Each year more land is used for pasture as cattle raising becomes more desirable.

Sinkholes are scattered through the cropland and pastures on almost every farm. Usually those in pastures that have precipitous slopes are fenced or filled. Deep sandy soils mask small subsurface pipes and wells by sliding and filling the hole by gravity and washing. Shallow soils expose rocky outcrops and well-defined sinks.

## Sinkhole Density and Land Use

Very few attempts have been made to count sinkholes to establish density ratios. The introductory chapter describes the extent of previous investigations. At the present time no counts have been made of sinkholes of Florida until the present research was undertaken in land use for agriculture. Several techniques were employed by the writer to reach

certain conclusions. A large mosaic was assembled from alternate air photographs, sinkholes were located with stereoscope and magnifying glass, and locations plotted on an overlay map (see Map 6 in Chapter III). The area selected was chosen because it is a major agricultural area located on the Bell-Trenton-Chiefland Limestone Plain. Sinkhole density over the whole plain is estimated to be about 4 per square mile, or about one sinkhole for every 160 acres. This estimate is probably low rather than high because in forested areas many sinkholes were obscured as well as was any existing orientation. Also it must be remembered that most of the sinkholes smaller than five feet in diameter could not be counted. There is a definite clustering pattern in some areas of open land. No clustering could be seen in forest land. The highest density in any square mile is 25, and there are a number of square-mile areas that do not have any sinkholes. One advantage to this type of count is that patterns and longitudinal trends in placement could be discerned. There is orientation in a northerwest-southeast direction as well as north-south and east-west strikes. This orientation as well as the clustering reflect the pattern of joints in the limestone directly beneath the surface. Differences in thickness of overburden doubtless influenced the surficial expression. There were fewer holes along the periphery of the plain where alluvial deposits and continuous forests occur.

Another tool for enumeration of sinkholes in agricultural lands is the topographic map. Selected areas were counted, calling a closed contour with hachures as a sink. Averaging counts of the several topographic quadrangle maps of the Bell-Trenton-Chiefland Limestone Plain showed about

24 sinks per square mile. This figure of one sinkhole for each 27 acres is a much higher figure than computed from the aerial mosaic. Another map used for a partial enumeration was the Alachua County Soil Map with sinkholes identified.[20] The highest density, 22 per square mile, occurred in sandy soils near High Springs. The sinkholes are scattered in a northwest-southeast orientation apparently irrespective of differences in soil type in the limestone plain of western Alachua County.

Field reconnaissance by the writer proved both counts to be less than actual numbers by a factor of up to 50 percent. Actual field observation was the only method feasible for counting outcrops except in the sample areas covered by the Conservation Needs Inventory, which yielded fairly accurate data on karst features. These counts were actually made in the field, however, and recorded on photos by soil scientists.

The Soil and Water Conservation Needs Inventory for Florida was developed as part of the National Inventory for the 50 states. The purpose was to provide information for federal departments and other agencies to use in programs for resource conservation. The first National Inventory was carried out in 1958 and updated in 1966. Its purposes include estimates of acreage in each land use and treatment needs for that use. Land uses are defined as follows:

Cropland—Land being used for field crops, tillage rotation, orchards and goves, temporarily idle land, and open land formerly cropped.

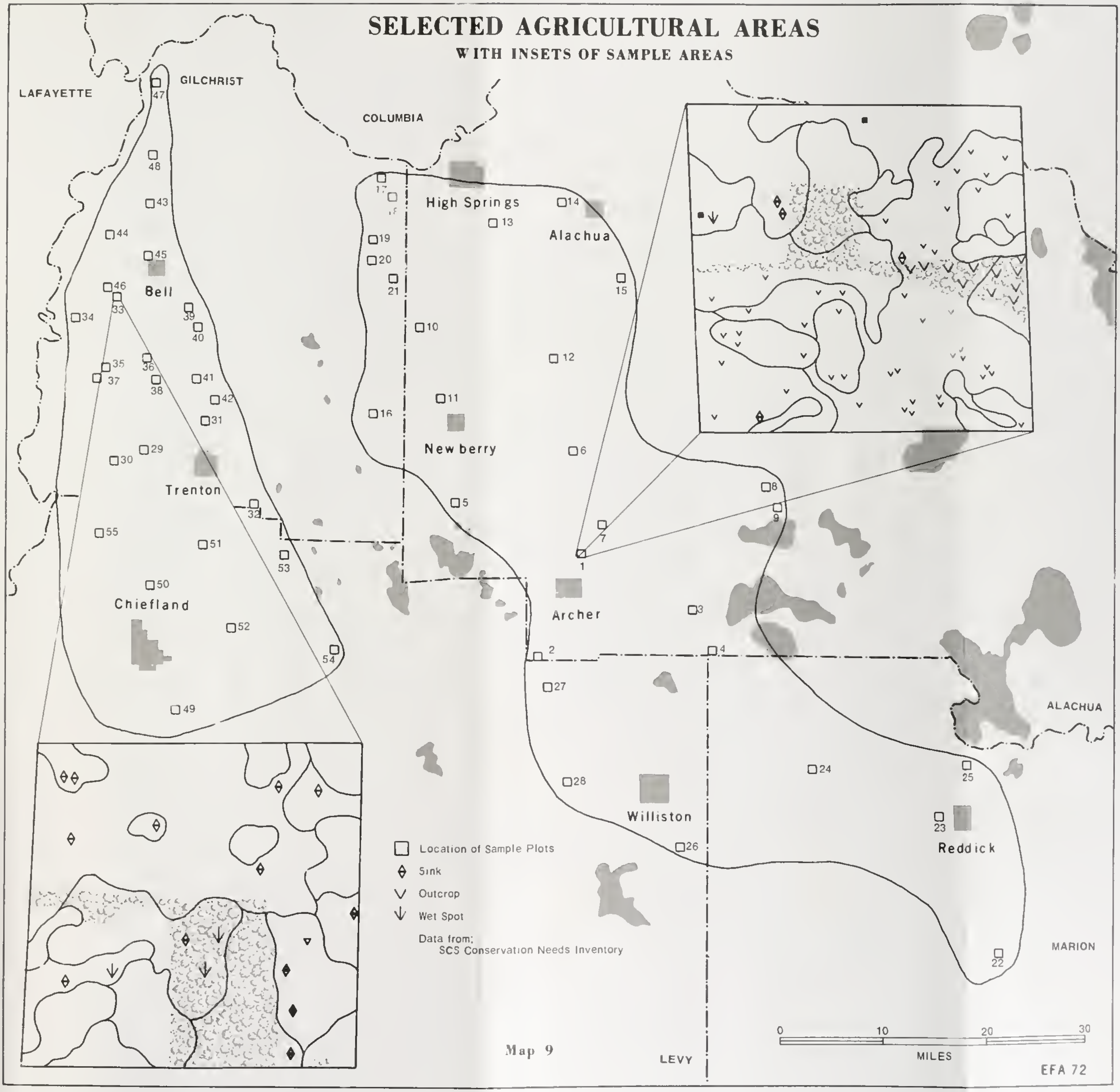
Pasture—Lands producing forage plants, principally introduced species, for animal consumption.

Forest—Land at least 10 percent stocked by forest trees of any size and not currently developed for a nonforest use.

Other land—The concept was changed between inventories. The 1958 inventory included most idle land in this category. The updating shows most of this in other uses. This is land which is not cropland, pasture, or forest land and includes strip mines, borrow and gravel pits.

In the process of inventory, the surveyors were directed to make note of sinkholes, outcrops, wet spots, and miscellaneous karst features, to serve as additional information to the primary purposes of the inventory. The updating in 1966 re-examined the same sample areas as were studied in 1958. Randomized samples were selected by the statistical laboratory at Iowa State University, and the sample units were located on county maps. The standard size of the sample unit was 160 acres. The basic sampling rate was 2 percent in a county or other area of 250,000 to 500,000 acres. The study area in the limestone plains sums to more than 400,000 acres, providing data of an acceptable degree of reliability. The intent was to county sinkholes and other karst features in land use types (see Map 9). An additional experiment was intended to provide data on karst features for lands of various soil types.

In updating the Inventory, a different system was used for obtaining more data from the sample areas. Each sample area was marked with random points (36 points per 160 acre sample area) at which time a record was made of conditions existing at the site of each point. A template was spun to give random orientation to the points and varied the number falling in the sample from 32 to 38. Land use determinations at each



SELECTED AGRICULTURAL AREAS
WITH INSETS OF SAMPLE AREAS
LAFAYETTE
GILCHRIST
COLUMBIA
High Springs
Alachua
Bell
Newberry
Trenton
Chiefland
Archer
Williston
Reddick
ALACHUA
MARION
LEVY
Location of Sample Plots
Sink
Outcrop
Wet Spot
Data from:
SCS Conservation Needs Inventory
0
10
20
30
MILES
EFA 72


Map 9

designated point were in terms of the field in which the point fell. Therefore, one point could be interpreted as representative of land use of 4.4 acres.

Fifty-five samples fell in the selected agricultural areas of the limestone plains which encompass Bell-Trenton-Chiefland and High Springs-Williston-Reddick. Every statistical treatment considered to prove valid was executed with the sample plots. The results have provided sinkhole counts generally, as well as counts categroized by land use.

These samples total 8,800 acres, or more than the 2 percent required for validity. Results are shown in the paragraphs which follow as percentages of land estimated to be in a particular land use and soil association category.

Cropland: The percent of land in the selected agricultural areas that was used for cropland in 1958 was 37 percent and it remained at this proportion in 1966. Of the total in cropland, more than four-fifths was on Jonesville-Chiefland-Hernando soils (numbers 4 and 9 on the soil map) despite the fact that the incidence of sinkholes was extremely high. Cropland counts yielded: one sinkhole per 35 acres, one outcrop per 54 acres, and one "other" karst feature (wet spot, karst pond, quarry, etc.) per 295 acres. The average is one karst feature for each 20 acres in cropland, which fact indicates that farmers do not avoid cropping lands with sinkholes if the lands are other wise suitable.

Forest: Thirty-three percent of the total land area was used for forest in 1958 and 36 percent in 1966. The largest amount of this forest was on Lakeland-Eustis-High Blanton soils (number 3) with few sinkholes

counted. Next highest count is on Jonesville-Chiefland-Hernando soils which have many karst features. Forest land counts show: one sinkhole per 56 acres, one outcrop per 22 acres, and one "other" per 50 acres. The average is one karst feature for every 12 acres of forest land. This high density was not perceptible from study of the stereo-pairs. It may indicate some land use changes from other uses.

Pasture: The proportions of land in pasture rose from 16 percent in 1958 to 23 percent in 1966. Largest amounts of pasture are found on Jonesville-Chiefland-Hernando and on Arredondo-Zuber-Fellowship soils (numbers 5 and 8). Highest incidence of sinkholes in pasture land is on soil grouping 5 - 8. In land used for pasture, there is one sinkhole per 51 acres, one outcrop per 9 acres, and one other "karst" feature per 63 acres. When the total number of these features is divided into the total acreage involved, an average of one feature per 7 acres results. This is the highest incidence recorded in the survey. Information derived from the case study interviews suggests that cropland sinkholes are treated by pushing in, whereas no such effort is exerted in pasture areas, since mechanical equipment is used much less frequently on pastureland.

The CNI count included a category labelled "idle and other lands." The chief use of this category is to base all acreage figures on 100 percent. The small amounts of land involved preclude drawing any relevant conclusions from this "filler" element.

## Land Use and Soil Type

An attempt was made to compare land use and soil types to determine whether there was any preference or lack of preference for using soils

with karst influences. The first step was to calculate what percent of total land was in each soil grouping. Soils with similar properties were grouped to simplify results. (See first part of Table 5.) This portion of the table relates the density of counted karst features to soil association. The second part of the table gives the percent of land in each land use, also by the soil associations numbered and named on the table.

Association 3 shows a disproportionately low density of karst features, which the writer believes may be attributed to the deep sands characteristic of this association, which fill in subsidence events and mask their surface expressions. There are more actual counted features on the Jonesville-Chiefland-Hernando soils (numbers 4 and 9) because more of the land is in this soil association than any other. The largest percent of the land classified as cropland is also in this association. Soils 4-9 directly overlie limestone, and subsidence is common. Soils 5-8 account for about one-sixth of the land and more than one-fourth of the counted karst features. These are mostly hammock lands, fertile, and influenced by the subsurface paleo-karst conditions responsible for the origin of the calcareous hammock soils in the first instance. The last two categories in Table 5 do not require comment.

## Land Use—Soil Type Correlation

In addition to the tabular matrix of data recorded in Table 5, a statistical problem was proposed to examine less obvious idiosyncracies. Using four land uses and five soil associations, an analysis of karst features in each of twenty categories was attempted. (See Appendix I.)

Table 5 Relative Proportion of Karst Count to Total Land and Per Cent of Land in Each Use, by Soil Associations, 1966

| Number on Soil Map (Map 4) | Names of Principal Soils | Counted Karst | Total Land | Cropland | Forest | Pasture | Idle |
|---|---|---|---|---|---|---|---|
| | | percent | percent | percent | percent | percent | percent |
| 3 | Lakeland<br>Eustis<br>High Blanton | 2 | 17 | 4 | 11 | 1 | 1 |
| 4 - 9 | Jonesville<br>Chiefland<br>Hernando | 58 | 52 | 29 | 9 | 7 | 7 |
| 5 - 8 | Arrendondo<br>Zuber<br>Fellowship | 27 | 17 | 4 | 6 | 5 | 2 |
| 12 | Kanapaha<br>Low Blanton<br>Klej | 5 | 5 | 1 | 3 | 1 | 0 |
| - | All<br>other<br>associations | 8 | 9 | 1 | 4 | 0 | 4 |
| | Totals | 100 | 100 | 39 | 33 | 14 | 14 |

100%

Source: Abbott, developed from sample plot photos and comprehensive reports in Conservation Needs Inventory, 1958 and 1966.

Fifty-five photos were used as the basis for a sampling count, each covering 160 acres on the Bell-Trenton-Cheifland limestone plain. It was decided first to compare all land use categories disregarding soil types and then to compare all soil types disregarding land use. The ultimate purpose was to ascertain numbers of karst features per land use—soil type category. (See Appendix I.)

The results suggest to this student that true numbers of features in cropland and idle land were less related to soil type than those in forest land or pasture land. Or, put another way, if land is perceived as cropland, it will be used as cropland, despite its karst features. There was also clear evidence that soils of group 3 were least affected by land use—soil type correlation.

## Soil Productivity

The present condition of the soil is the result of continuous action of cultural influences and physical factors. No doubt soil structure and composition reflect the presence or absence of limestone near the surface. Drainage factors and subsequent erosion damage also indicate subsurface geology.

The actual productivity of the soil is best judged by examination of crop yields under certain conditions. Production data for the Georgia-Florida physiographic area were selected as a broad basis for comparison. These data were published by the U. S. Study Commission for the Southeast River Basins in 1961, and indicate average yields computed annually over a 35-year period for crops grown in the Coastal Plain Physiographic Province. The figures were adjusted to account for extremes influenced

by climate, etc., hence are "normalized." As such, they may be used for comparison against figures for any given individual year, such as census years, for example. Table 6 lists crops selected as common to both the west central Florida counties and the Coastal Plain.

For the study area, average yields computed for Gilchrist and Levy Counties, as compiled by the Census of Agriculture, 1964, indicate the comparative productivity of the limestone plain. (See Tables 7 and 8.) These counties were chosen as representative because most of their farming areas are in the limestone plain chosen for sampling.

Additional information given in Table 6 shows possible yields under various management practices.[21] Group A includes farmers who use average to below average management practices for seedbed preparation, fertilization, seed selection, cultivation, and use of pesticides. Most of the farmers in Gilchrist and Levy Counties are considered to conform to Group A criteria. Group B makes full use of all applicable recommended management practices except irrigation. Only a few farmers practice irrigation in the study area, tobacco and truck crops being most affected. Management Group C encompasses all criteria for Groups A and B plus irrigation. This factor gives Group C very high yield estimates which affect the summarized figure for "All Levels." This figure is a weighted average, computed by use of percentages of land in each management level group. Thus, the tables show the limestone plain to be producing close to average yields for corn, somewhat lower than average for tobacco production, and moderately high yields for peanut crop production.

Table 6 Normalized Average Yields for 35-Year Period: Coastal Plain Physiographic Area

| Enterprise | Unit Per Acre | Management Levels* A | B | C | All Levels (wt'd avg) |
|---|---|---|---|---|---|
| Corn | bushels | 20 | 40 | 58 | 25 |
| Tobacco - flue-cured | pounds | 850 | 1516 | 1836 | 1379 |
| Peanuts | pounds | 759 | 2135 | 2523 | 1046 |
| Hay: Coastal Bermuda | tons | 2.12 | 4.34 | 5.69 | 2.60 |
| All other | tons | 1.22 | 2.50 | 3.28 | 1.50 |

* Level A: Average Management Practices

Level B: Improved Management Practices without irrigation.

Level C: Improved Management Practices plus irrigation.

Source: U. S. Study Commission, Southeast River Basins, 1961.

Table 7 Selected Crop Yields Computed for Gilchrist County

| Enterprise | Unit Per Acre | 1954 | 1959 | 1964 |
|---|---|---|---|---|
| Corn | bushels | 14 | 25 | 27 |
| Tobacco - flue-cured | pounds | 998 | 1151 | 1442 |
| Peanuts | pounds | 767 | 820 | 1197 |
| Hay: Coastal Bermuda | tons | NA | NA | 2.22 |
| All other | tons | .94 | 1.3 | .76 |

Source: Census of Agriculture, 1954, 1959 and 1964

Table 8 Selected Crop Yields Computed for Levy County

| Enterprise | Unit Per Acre | 1954 | 1959 | 1964 |
|---|---|---|---|---|
| Corn | bushels | 15 | 21 | 26 |
| Tobacco - flue-cured | pounds | 991 | 1031 | 1295 |
| Peanuts | pounds | 636 | 912 | 1502 |
| Hay: Coastal Bermuda | tons | NA | NA | 2.31 |
| All other | tons | .91 | 1.32 | .76 |

Source: Census of Agriculture, 1954, 1959 and 1964

The soils of the agricultural area may be considered also and have been grouped for this purpose. Information available indicates that no significant differences prevail in average yields for a given soil group by river basins within a physiographic area.[20] Therefore, data for the Suwannee River Basin soils are considered to be fairly accurate measures of area soil productivity (see Table 9). Highest yields in the basin areas for corn are in soil grouping 5 - 8 (which once was mostly high hammock land). These are the calcareous hammock soils typically of the Zuber-Fellowship Association. Lowest yields are in the areas of Hernando-Chiefland soils which are almost directly overlying limestone and are locally eroded and sometimes wind blown.

Tobacco yields appear highest in the sandy soils of the former rolling pine lands. These are Lakeland, Eustis, and High Blanton Associations often with a deep sandy profile. Limestone is several feet below the surface, but its irregular contours influence the topography greatly. Lowest yields are again in the Hernando-Chiefland grouping.

Peanuts do well on the same soils that are good for corn. They also yield profitably on the sandy soils of Association 3. They are not suited especially to the Hernando-Chiefland or to the Prairie Land soils. Patterns for hay follow those of corn and peanuts, with the alternately wet and dry prairies being best suitable.

The influence of the limestone on the soils and thence on the suitability of the land for crops is obvious here. Culturally instilled farming methods have had some effect upon decisions made by

Table 9 Average Yields Per Acre and Management Level,* Coastal Plains Physiographic Area, by Soil Types

| Soil Grouping and Land Type | | Corn (bushels) A | B | C | All (wt'd avg) | Tobacco (pounds) A | B | C | All (wt'd avg) |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Pine Land | 15 | 37 | 48 | 20 | 855 | 1412 | 1710 | 1306 |
| 4-9 | Hammock & Mixed | 7 | 18 | 44 | 10 | 446 | 743 | 1635 | 907 |
| 5-8 | High Hammock | 36 | 44 | 67 | 30 | 855 | 1412 | 1710 | 1306 |
| 12 | Prairie Land | 15 | 26 | 33 | 17 | 743 | 1487 | 1784 | 1316 |
| % of land in these management levels | | 80 | 17 | 3 | 100 | 35 | 35 | 30 | 100 |

* Level A: Average Management Practices.

Level B: Improved Management Practices without irrigation.

Level C: Improved Management Practices plus irrigation.

(continued)

Source: U. S. Study Commission, Southeast River Basins, 1961.

Table 9 (continued)

| Peanuts (pounds) | | | | Coastal Bermuda Hay (tons) | | | | Other Hay (tons) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | All (wt'd avg) | A | B | C | All (wt'd avg) | A | B | C | All (wt'd avg) |
| 707 | 2262 | 2488 | 1025 | 2.54 | 4.44 | 5.71 | 2.96 | 1.47 | 2.56 | 3.29 | 1.71 |
| 566 | 1131 | 2488 | 720 | 1.27 | 2.54 | 5.07 | 1.60 | .73 | 1.47 | 2.93 | .92 |
| 820 | 2262 | 2601 | 1119 | 2.53 | 5.07 | 6.34 | 3.08 | 1.46 | 2.93 | 3.66 | 1.78 |
| 466 | 1697 | 2036 | 802 | 1.27 | 2.54 | 3.80 | 1.56 | .73 | 1.47 | 2.19 | ..90 |
| 80 | 17 | 3 | 100 | 80 | 17 | 3 | 100 | 80 | 17 | 3 | 100 |

individual farmers to grow certain products. Changes in land use are frequent, but the proportion of land in crops remains fairly stable when considering the entire region. The Conservation Needs Inventory showed that a change in major use (cropland, forest, pasture, and idle) had occured on 36 percent of the acres surveyed. Yet the percentages of land in each use remained fairly stable, probably reflecting response to economic stability.

The foregoing statistical analysis demonstrates that there is no significant correlation between soil types versus land use versus the relative density of karst features, under today's conditions. From this it follows in the judgment of this writer that users of the land have resorted to such use as their individual circumstances dictated, and that such use has been made despite the presence of karst features, rather than because of them. Karst problems appear to have been a nuisance element to individuals, and while they could be important at times, they were only one of a number of problems with which land users had to contend, namely markets, prices, transportation, booms, and busts, among others.

## Case Studies

Ten farms of the limestone plain were selected for closer study with the help of the Agricultural Stabilization and Conservation Service agents in Trenton and Bronson. The principal objective was to provide a set of actual field conditions to hold as a frame of reference while other techniques were employed in data collection. Informal interviews

were conducted and systematic questions put to each farmer (see Appendix II). The farms ranged from 240 acres to 2,000 acres in size. According to the 1964 Census of Agriculture, the case study farms are larger than the average for the counties being considered.[22] There were three reasons for the selection of the particular group interviewed: (1) the farm large enough in size to keep the farmer full-time on the land: (2) the location of the farm on the part of the plain already subjected to detailed analysis by photo interpretation; and (3) the recommendation of the government specialists, before mentioned. There is sufficient evidence to state positively that the selected farms are not considered typical, but are thought to be representative of the total spectrum of farms in the part of the study area delineated as agricultural land.

Maps of individual farms were prepared by using the eight inches to one mile (1" = 660') scale of the ASCS office aerial photographs. Topographic maps were enlarged to the same scale to compare field patterns to topography. Sinkholes or outcrops are present on all farms studied but vary greatly in size and description. The farmer knows the location of the larger or older karst features on his land. In interviews, he usually disparaged the value of his personal time used in involvement with sinkholes. The holes are considered only a nuisance until "cash" money is lost when stock animals are killed. Then they become a subject for action!

Replies to the questions varied in the ten cases cited here. All of the farmers seemed willing and even happy to "share" their experiences with sinkholes. One proudly displayed a homemade blade which when

mounted on a tractor was used for filling sinkholes. A few have amassed partially accurate technical information on their sinkholes, one asserting that his farm's sinkholes connected with the Suwannee River, another quoting "University People" as saying his farm had the purest limerock in the state.

A typical farmstead on the limestone plains sprawls on flat land amidst shade trees. Farmyards and lanes are likely to be dusty with equipment and machinery left parked in casual fashion. There is usually a fenced kitchen garden off to one side with seldom any fruit trees, berry bushes, flower beds, or other productive amenities about. There will be, however, ubiquitous borders of limerock and occasional piled-up limerock boulders. Usually there are sheds and pens for swine which somehow always seem to have gotten loose. Dogs and cats abound. The dogs are of no particular type, but on the occasions of the interviews were always noisy and friendly. Tobacco fields are usually found close by the homesteads, as are the easily recognized tobacco barns.

There was a wide range of response to the treatment of karst hazards. In some cases bundles of old fence wire, tires, or timbers marked the presence of sinkholes in the fields. Other sinkholes served as farm trash pits and their owners observed sternly that this practice was much better than certain of their neighbors "that dumped their trash right out on the land."

Land uses vary widely in the case studies with cropland occupying somewhat less than half the land. This is compatible with the figures of the Conservation Needs Inventory though all the farms are fairly

large and one is predominantly pasture. Typical problems include such as that illustrated in Figure 13. The corn field has been partly lost because of the drainage problem. The individual farmers tell of trouble with livestock, and the small treacherous sinkholes illustrated in Figures 5 and 18, found in Chapters II and V.

The case farms contain from 2 to 30 or more sinkholes each, and most have some rocky outcrops. At least three of the farmers had taken advantage of the ASCS program wherein the federal government matches funds used to fill sinkholes. One farmer, having lost 32 hogs in past years, had spent $1,500 in this program. The Levy County ASCS agent reports, however, that the plan has not been well-accepted because of the expense. More discussion of this problem will be presented in the following chapter.

The case study farmers use tractors and tobacco harvesting machines, but do not attempt to utilize such equipment as valley sprinklers (see Figure 14). This large piece of irrigation equipment could not function on a sinkhole-pitted terrane. It will operate on undulating slopes but the wheels must be able to roll along the ground without obstructions or traps created by voids. Only one farmer had plowed along the contour around a sinkhole (see Figure 15). This action seems to be unique today but has been practiced in past years.[23] In only one of the case studies did the farmer have a sinkhole that he considered as an asset. This sinkhole has a well in it for irrigation purposes. In no case was there standing water for stock, although these farm ponds can be seen occasionally on other farms in the study area.

Figure 13 -- Adverse Drainage Conditions in Cornfield North of Alachua

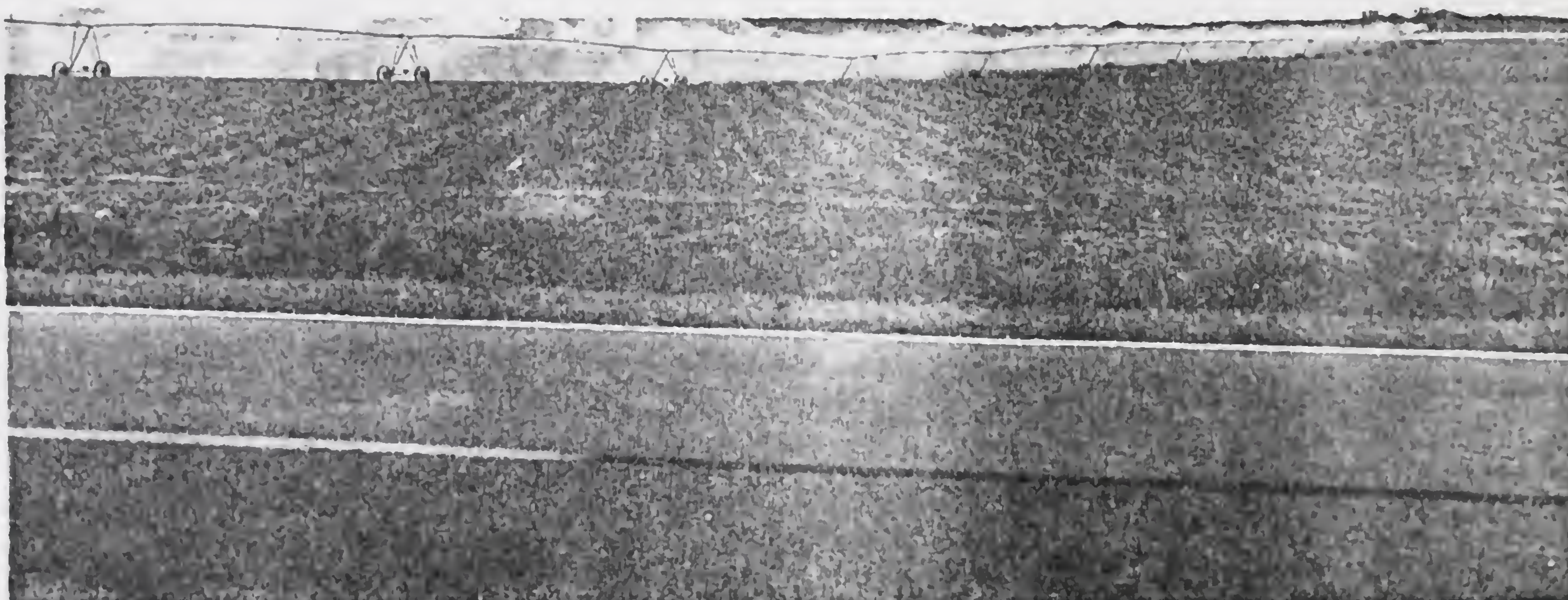


Figure 14 -- High Degree of Mechanization Possible (Valley Sprinkler) When No Sinkholes are Present (Near High Springs)

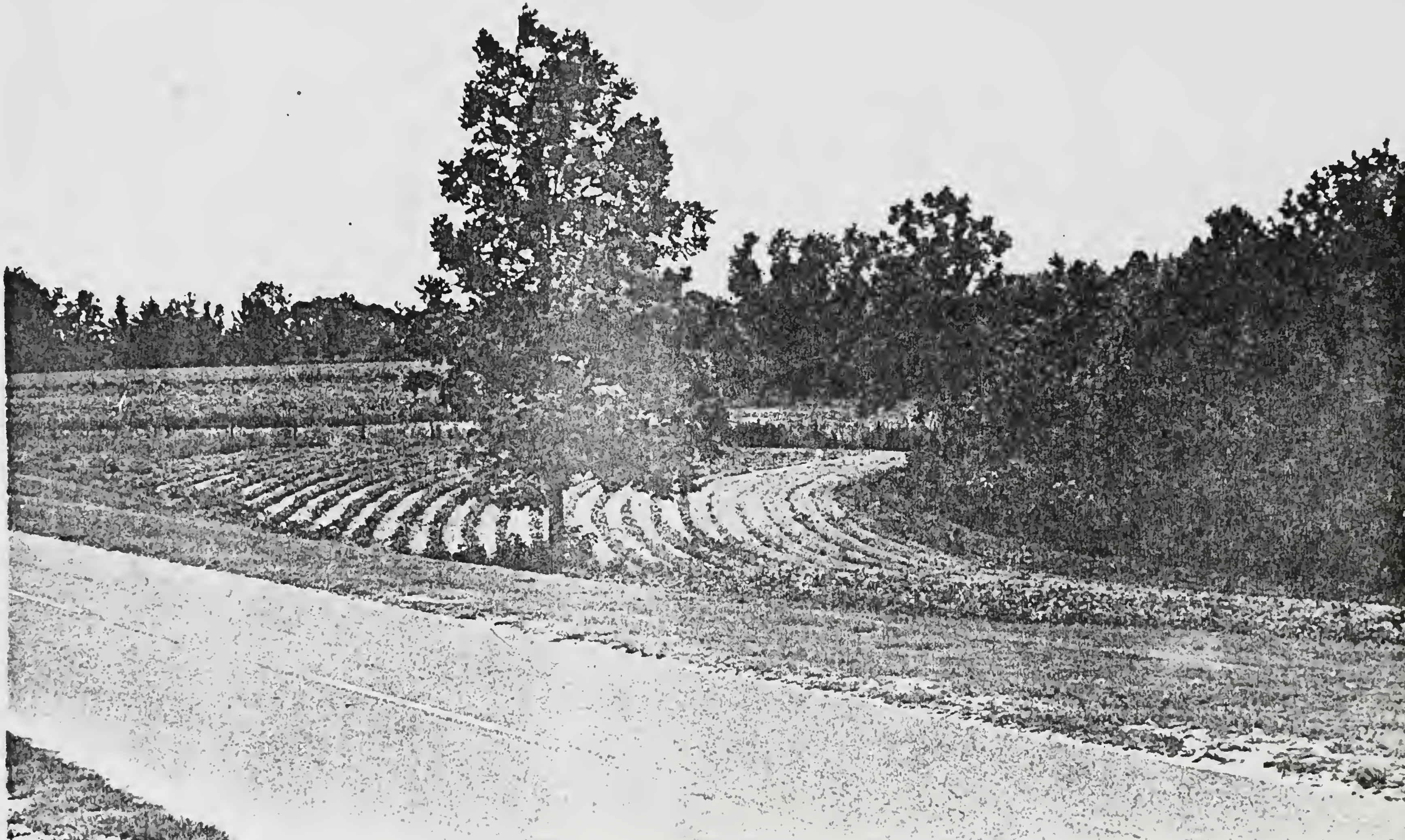


Figure 15 -- Effective Efforts to Retard Excessive Drainage Around Sinkhole, Northern Alachua County

Field data from the case studies support the statistical analysis of karst data, as reported in the section preceding. Farmers appear to use karst lands according to their various individual circumstances, and while recognizing karst problems, seem accustomed to them, and in the sampling reported upon, tolerated the problems without overly reacting to them. The chief benefit to the writer derived from the accumulation of case data is the increased ability to perceive more clearly some of the relationships between karst and land use and to recognize some of the problems associated with using land having numerous karst features.

## NOTES TO CHAPTER IV

[1] E. H. Sellards _et al._, "Natural Resources Survey of an Area in Central Florida," _Seventh Annual Report_, Florida State Geological Survey (1915), p. 196.

[2] W. T. Cash, _The Story of Florida_ (New York: American Historical Society, 1938), p. 763.

[3] Sellards _et àl._, "Natural Resources Survey of An Area in Central Florida," p. 197.

[4] Florida Agricultural Experiment Station, _Soil Survey, Alachua County, Florida_ (University of Florida, 1954), p. 9.

[5] _Ibid._

[6] Willie Kate Tyson, "History of the Utilization of Longleaf Pine (_Pinus palustris Mill._) in Florida from 1513 until the 20th Century" (University of Florida Thesis, 1956), p. 67.

[7] Sellards _et al._, "Natural Resources of an Area in Central Florida," p. 133.

[8] Florida Agricultural Experiment Station, _Soil Survey, Alachua County, Florida_, p. 10.

[9] The Tobacco Institute, Inc., _Florida and Tobacco_ (Washington, D. C., 1960), p. 19.

[10] _Ibid._

[11] Cash, _The Story of Florida_, p. 201.

[12] Sellards, _et al._, "Natural Resources of an Area in Central Florida," p. 140.

[13] Florida Agricultural Experiment Station, Soil Survey, Alachua County, Florida, p. 12.

[14] Sellards et al., "Natural Resources of an Area in Central Florida," p. 133.

[15] Francis Joseph Marschner and Lawrence Adkins Reuss, Inventory of Major Land Uses in the United States (Washington: United States Government Printing Office, 1948).

[16] Ibid., inside front cover.

[17] E. T. Pyle, Home Country (New York: William Sloan Associates, Inc., 1947), pp. 340-341.

[18] Florida State Agricultural Stabilization and Conservaton Service, pamphlet, Pensacola Bahia (1959).

[19] United States Soil Conservation Service, Florida Conservation Needs Inventory (1958 and 1966), p. 20.

[20] Florida Agricultural Experiment Station, Soil Survey, Alachua County, Florida, 1954.

[21] C. V. Lyle and T. G. Toon, "Normalized Crop and Pasture Yield Estimates (Current 1960, and Projected, 1975 and 2000)," Southeast River Basin's Study Area, U. S. Study Commission, United States Department of Agriculture (March, 1961), p. 9.

[22] United States Census of Agriculture (1954, 1959, 1964).

[23] E. H. Sellards, Underground Water Supply of Central Florida, Florida State Geological Survey (1908).

# CHAPTER V

# HAZARDS AND PROBLEMS ASSOCIATED WITH KARST

## Dimensions of the Problem

The peculiar or distinguishing features of the karst landscape are those landforms attributable to a dominance of the process of solution in their formation. The mass wasting of the surface downward by gravity follows solution underground. Since this subsidence is usually more local in extent than regional because of differential solution, the resulting surface expression is that of a void or hole. If the hole existed before the land use was determined, perhaps the presence of the sink would remain a problem or condition to be considered and planned for--or ignored. If the subsidence occurs after the land is in use, there may be loss to person or property. The importance of the loss is proportional to such variables as land use and the presence of structures or livestock.

The problems associated with karst topography most often center themselves about sinkholes and outcrops. The agricultural land use may be altered by these physiographic features. The situation could be the presence of a large sinkhole in some of the better soil areas for crops. This occurrence is not accidental, for the Jonesville-Chiefland-Hernando soil association is considered suitable for use as cropland in the area. The underlying limestone possesses the characteristics that predispose the area to cavities and subsequent sinkholes. Outcrops of

limerock at the surface present a serious condition also, rendering much of the land where they occur unsuitable for productive use. Outcrops may have been present at the time of initial use of the land by man or they may occur as recent exposures of the bedrock by tillage erosion of the overlying soil.

Whether the surface expression is positive or negative in relief, a problem exists when the land is used. The small sinkhole is often filled by the farmer with loose rocks which must be removed from the cropland. With the passage of time the karst feature becomes almost unidentifiable as to its origin as sink or outcrop. The ubiquitous rockpile surrounded by bushes and often trees is a wasted portion of the farm and a negative resource.

There are other hazards attributable to karst besides those involving tillage pursuits, including, as has been noted, the loss of livestock and of human life as well. The term "hazard" connotes some degree of risk, so the use of the word "problem" is also warranted. When a major cave-in occurs unexpectedly there is peril or hazard to person and property. When the karst feature is already present and real, it can be dealt with as a problem.

Sinkhole hazard, therefore, conforms to the definition of natural hazards proposed by Ian Burton and Robert W. Kates in their article "The Perception of Natural Hazards in Resource Management."[1] Natural hazards are those elements in the physical environment "harmful to man and caused by forces extraneous to him."[2] Burton and Kates also describe the insurance concept of "act of God" and offer that today's

acts of God "are often tomorrow's acts of criminal negligence." The creation of a sinkhole is almost always perceived as unavoidable and an accident, when in fact real causes exist which are to some extent preventable if not predictable.

The farmers of the case studies as well as dozens of other residents who were interviewed showed degrees of variation in their perception of the natural hazard of sinkholes. However, taken collectively they exhibit considerable cultural uniformity in this perception. To the native inhabitants of the study area karst hazards are physical phenomena caused by forces extraneous to themselves. Their perception of these hazards is so casual as to amount to general acceptance. To persons entering the area from other regions of the state, such as, for example, a new county agent transferred from West Florida, the hazards are real and apparent and demanding of consideration. This is perception to an immediate and high degree. Man's perception of these hazards, therefore, is seen to operate on two levels; a low level perception shared by those individuals long inured to the hazards, and on a higher level those individuals whose perception is fresh and who are habituated to the solution of problems.[3] Such differences within a group and between groups are well understood and frequently encountered. Burton and Kates say, within the precise context of variations of the perception of natural hazards, that in a profound and fundamental way such variation is a product of human ignorance.[4]

With the foregoing in mind, Table 10 from the Burton and Kates article was selected for inclusion here. The table lists common natural

Table 10 List of Natural Hazards with Sinkholes Added

| Geophysical | | Biological | |
|---|---|---|---|
| Climatic and Meteorological | Geological and Geomorphic | Floral | Faunal |
| Blizzards & Snow | Avalanches | Fungal Diseases<br>For Example: | Bacterial & Viral Diseases<br>For Example: |
| Droughts | Earthquakes | Athlete's foot<br>Dutch elm<br>Wheat stem rust<br>Blister rust | Influenza<br>Malaria<br>Typhus<br>Bubonic Plague |
| Floods | Erosion (including soil erosion & shore and beach erosion) | | |
| Fog | | Infestations<br>For Example: | Venereal Disease<br>Rabies<br>Hoof & Mouth Disease<br>Tobacco Mosaic |
| Frost | Landslides | | |
| Hailstorms | Shifting Sand | Weeds<br>Phreatophytes<br>Water Hyacinth | |
| Heat Waves | Tsunamis | | Infestations<br>For Example: |
| Hurricanes | Volcanic Eruptions | Hay Fever | Rabbits<br>Termites<br>Locusts<br>Grasshoppers |
| Lightning Strokes & Fires | Sinkholes* | Poison Ivy | |
| Tornadoes | | | Venomous Animal Bites |

*Suggested addition by E. F. Abbott

Source: Burton and Kates (1964)

hazards by principal causal agent.[5] Their list covers a broad spectrum in descending order of magnitude from earthquakes down to fog and water hyacinths, but surprisingly fails to include sinkholes on karst terranes. For purposes of this study the sinkholes will be added to the list of geological and geomorphic natural hazards.

<u>Hazardousness of Place</u>

The extent and nature of damaging events in a regional ecology were examined by Hewitt and Burton for the University of Toronto, who made compilations of such events and from them applied the term, "hazardousness of a place." Their study is applicable to the karst country of west central Florida in important respects. Any natural hazard is a function both of the physical event itself and of the state of human society, including specifically the adjustments adopted to cope with the hazard.[6] The point is of fundamental importance and is directly applicable to the study area. The Florida condition is one of small-scale hazards, when measured against major catastrophes, but these hazards do small amounts of damage, frequently and cumulatively. Thus, because the economic and human costs of the hazard do not build up suddenly, they do not attract much public interest, in contrast with the sudden catastrophes of storm or flood which cause immense loss in a short time. The hazard is real nevertheless and is characteristic of the study area.[7]

The overall relationship between man and environment is involved here. On the positive side the relationship includes resources and

resource commodities, and on the negative side, hazards and damage. The ecological system of the study area can be seen to contain both, and our focus here is on the negative aspects. The natural elements of the karst which cause the damage are closely integrated with man's activities and sources of livelihood, and do not receive any particularly separate perception from the people on the land. Their threshold of tolerance to karst hazards is high, and such high tolerance levels increase the hazardousness of the place. The threshold height can not be stated precisely, however, because of the extensive range over which the karst hazards constitute, to one section of the community, hazards which are cancelled out, at least in economic terms, by benefits to another group. This condition is recognized by Hewitt and Burton and is examined in detail elsewhere in this dissertation in the chapter on "Limestone as a Resource."[8]

Governmental planning on the local level does however recognize at least the marginal hazards of the karst features, and has implemented programs to mitigate them. An earth scientist can go farther ahead to estimate the potential for future damage on a scale not experienced before, when he observes human activities changing natural conditions sufficiently to create the new hazard potential. These considerations are amplified in the material which follows.

Hazards to Structures

Sinkholes when present may offer the chief threat to structures. The extent of the problem was reported upon by the State Geologist of Florida following a request by the State Treasurer made in 1967.[9] Genesis of the request was a sinkhole problem in Polk County, which had

resulted in the loss of four homes in a subdivision (See Figure 16), and the temporary abandonment of 20 others. In the cases of the four lost through destruction, the FHA absorbed all losses beyond the home-owners' equities. These latter lost the amounts of their equities, since sinkhole insurance did not exist, and the houses were completely destroyed. The State Treasurer at that time was also Chief of the State Insurance Division and used the State Geologist's analysis as the basis for new state legislation making it compulsory for all insurance companies which sell fire insurance within the state also to add sinkhole insurance as an available option. The law took effect on January 1, 1970, and coverage has been available since that date.[10] (See Figure 17)

One feature of the geologist's report was the division of the state into vulnerability zones, termed "Zones of Probability," and divided on an ascending scale into categories one through four (See map 10). Most of the land surface of the dissertation study area is assigned to zones two and three. Their technical description is succinct and is quoted in full:

Classification of Karst into Zones of Probability

| | |
|---|---|
| Area I | Limestone covered by moderate to thick overburden, in which the water table and/or piezometric surface lies near or at the ground surface--Includes area of Florida in which artesian flow occurs. |
| Area II | Limestone covered by moderate overburden with the water table or piezometric surface lying below the top of sink basins. A well developed karst present, intersected in large part by the water table. |
| Area III | Limestone lying at or near the ground surface with thin overburden. Well developed karst. |

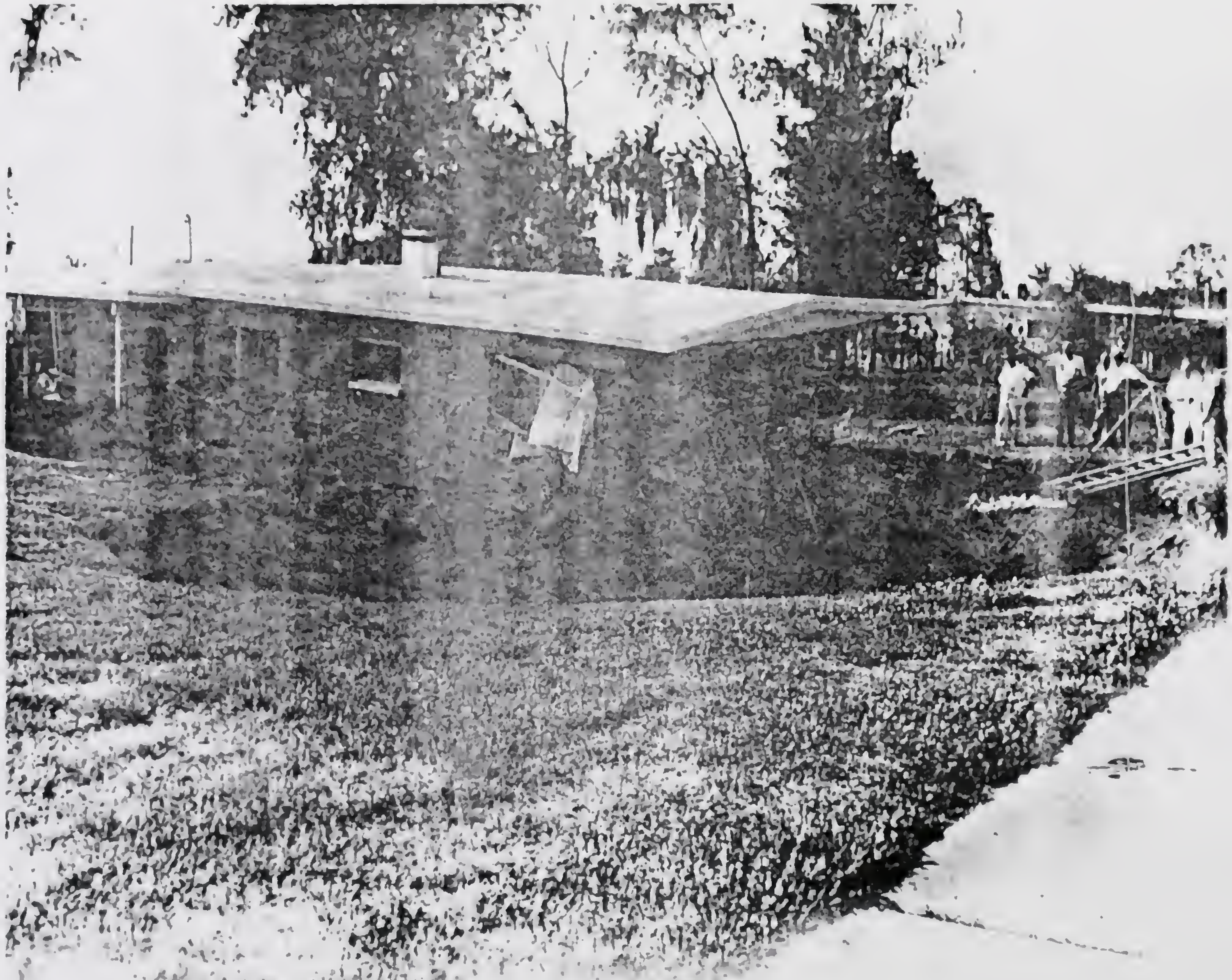
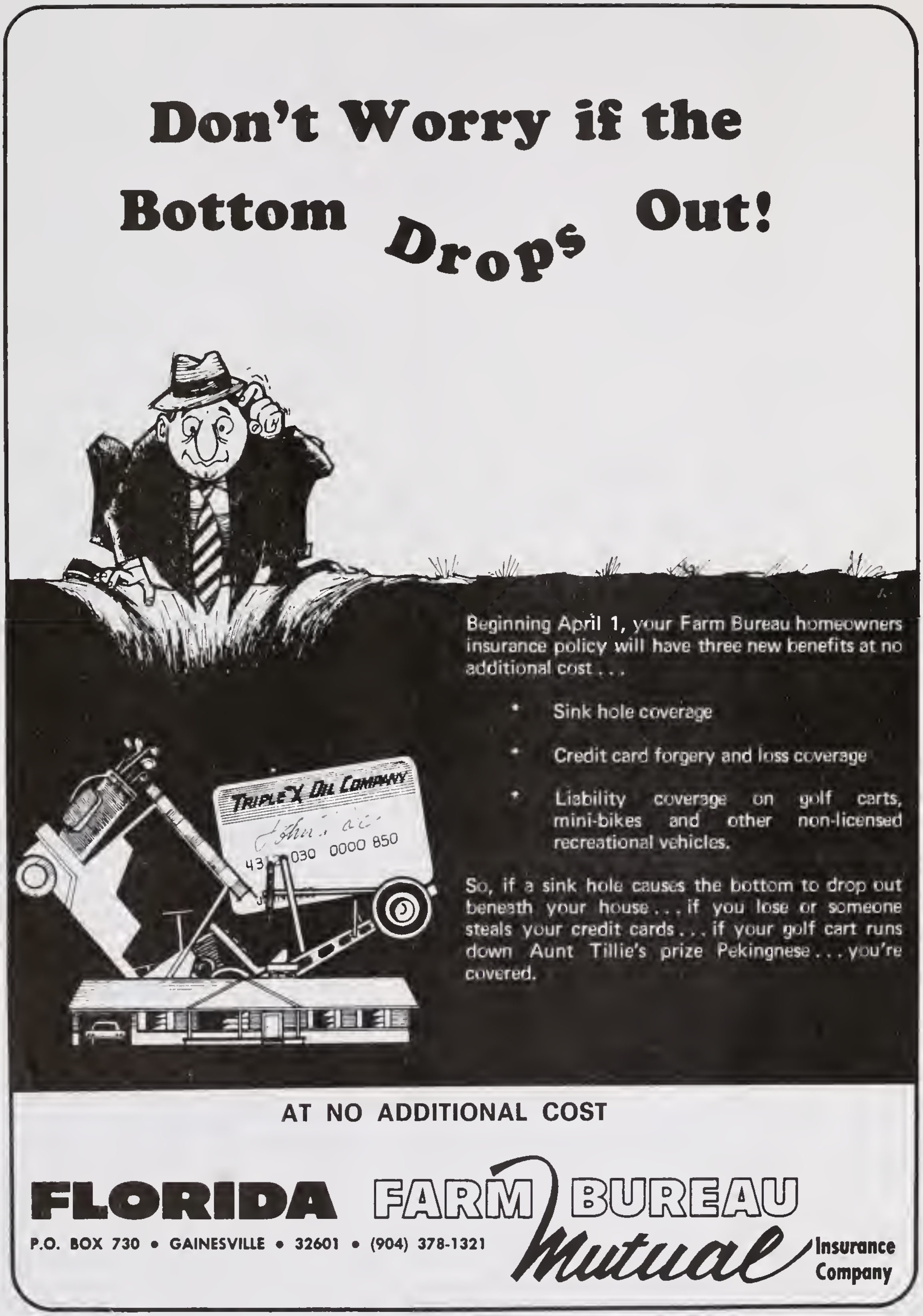


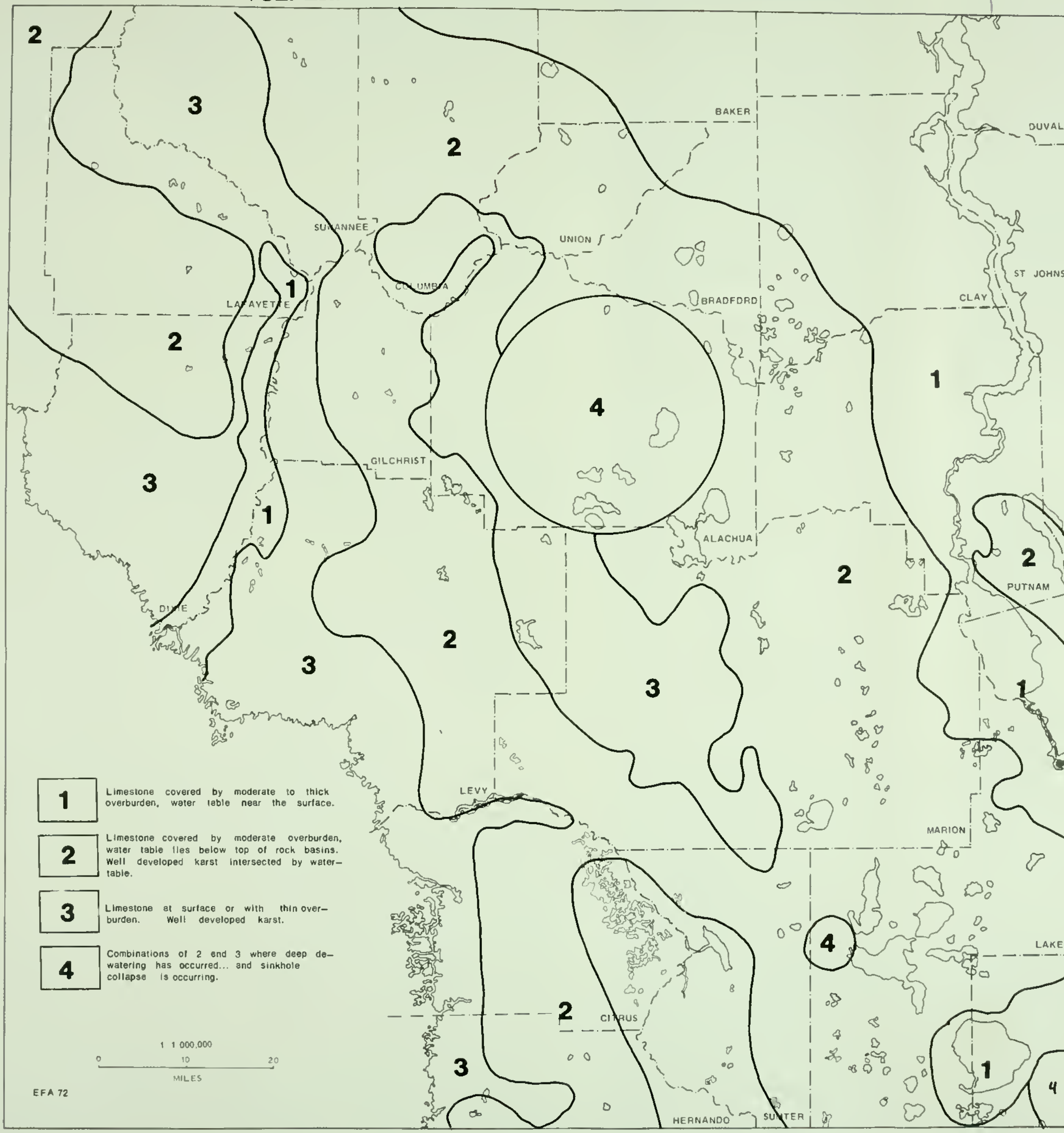
Figure 16 -- Residential Sinkhole Damage: Courtesy Bartow Area Civil Defense.




Reprinted From *FloridAgriculture* Magazine

Figure 17 -- Specialized Insurance Programs for Sinkhole Coverage, Advertisement.

# VULNERABILITY OF AREAS TO SINKHOLE DAMAGE




Map 10

SOURCE: Vernon, Report to the Legislature

Area IV Combinations of Areas II and III, where deep dewatering has occurred--and sinkhole collapse is occurring through dropping of deep and wide plugs of earth.

The Area definitions served as guidelines upon which the new insurance fees were to be based, and represent the State's best understanding of the extent and seriousness of the hazards. In 1970, for Alachua County, the premium rate was $.25 per $100 of insurance carried per building with limits of $17,500 on single family dwellings, and $30,000 on multiple dwellings up to and including four families. For Citrus, Dixie, Gilchrist, Lafayette, Levy, and Marion Counties, the rate was $.15 per $100 per building; and for Sumter County, the rate was $.06 per $100.

The Florida Farm Bureau Mutual Insurance Company announced that beginning April 1, 1972, its policy holders covered with homeowners insurance would receive--at no additional cost--sinkhole coverage. A company spokesman announced that their experience showed that the premium charges for sinkhole coverage at the owner's option were "not in line with the loss experienced, and that as a service to the customer-public it would be unfair to continue charging those high rates".[11] Since periods of years go by in Florida without the payment of insurance claims for hurricane losses when there have been no hurricanes for those years, it must be considered that the length of time the insurance law for sinkholes has been in effect is too short to permit conclusions at this point.

The State Geologist's Report is pertinent to the study area for other reasons than the mapping of relative vulnerabilities, and the making available of sinkhole insurance to the residents. The report, which is unpublished and limited in distribution, offers certain conclusions which apply here.[12] These are:

1. Sinkholes are a result of a natural geomorphic process that has functioned for several million years to produce the karst of Florida and to form the basis for the several thousand lakes that moderate the State's climate and provides recreation and a pleasant life.

2. Sinkholes will continue to form; that is a certainty--

3. Cavities which serve as receptacles for overburden collapse have been in existence for long periods of time.

4. The downward movement of ground water charged with carbon dioxide and organic acid is modifying and slowly enlarging vertical fractures and cavities in the limestone.

5. Subsurface cavities and surface sinkholes can be in part related to verticle fracture systems, and horizontal permeability.

6. There is some correlation of density distribution of sinkholes to land forms (swamps) and to the intersection of two land form types. This may be a real or an apparent relationship.

7. With deep dewatering of the sub-surface the numbers and rate of formation will be accelerated, coincident with droughts.

8. Land types I and II are virtually free of collapse features and probably will continue to be free until large dewatered areas are developed.

9. Land type III is limestone exposure, with attendant small sinkholes and karst. Limited foundation exploration should restrict structural failure.

10. Land type IV includes areas where deep dewatering coincided with a moderate clastic overburden, and a history of sink collapse. However, even within these areas, a combination of cavities in limestone, moderate and clastic overburden, low water levels, all must exist beneath a site before collapse occurs.

11. In areas having historical collapse and studied intensively, sinkholes were rare on hills and high flatlands, moderate in large basins of old sinkholes and streams, and common along the base of the slope connecting the hills to the basins. High on the slopes few sinks had occurred.

12. The location of sinkholes is probably related to bedrock structure, but the detail and degree has not been established.

13. Geophysical devices and data therefrom are highly interpretive and can be realistically utilized only for very shallow cavities. In the Bartow, Gainesville and Orlando areas, this depth range would be above the top of the limestone.

14. <u>No cheap means is now available to isolate specific small areas as to its relative degree of sinkhole development probability</u>.

While no insured residences at the time of writing have been damaged sufficiently for insurance claims to be filed, major structures planned in the study area require carefuly survey of the sub-surface areas before construction proceeds.* An example of such a survey is quoted from the report of an engineering geologist to the planners of a large office building in Alachua County in 1972.[13]

> Exploratory borings were made at the proposed building site...boring number one indicated the possible existence of a cavity in the limestone at a depth of 20 to 25 feet below grade...indicators point to existence of a well developed solution cavity which has been infilled with sediments. Aerial photographs and on-site inspection revealed a number of sinkholes and subsidence depressions in a line some three miles long trending SW-NE across the northeastern portion of your property. We might move off this joint lineation and obtain better foundation conditions by shifting the exploration some 80 to 100 feet east of the original location.

It will be seen that the engineering geologist's work conforms to conclusions 5, 9 and 10 of the State Geologist's report previously referred to. Professional sub-surface exploration is expensive and of course adds to construction costs, in direct response to the potential hazard of

*State Farm Mutual Insurance Company, Gainesville, Florida.

building over untested karst terrane.

The University of Florida itself has had considerable experience with the sinkhole and cavern problem. When pre-construction test borings for a new engineering complex indicated construction could proceed, excavation of the foundation was begun. Irregular caverns were encountered which had been missed by the systematic test borings. Expensive filling measures were required which had not been budgeted for in contract estimates.* In other cases relocation was required and a new set of costs incurred in planning for new sites.

In summary, then, the study area includes areas three and four of the highest vulnerability to sinkhole damage. Based on the Polk County experience of 1967, the state insurance authority through the legislature required sinkhole insurance to be provided for homes where desired, statewide. It is possible that companies avoided offering sinkhole insurance because of a lack of actuarial experience prior to passage of the bill. The possibility is given support by the resistance offered to the proposed insurance requirement when the senate held hearings on its bill. After passage, the companies took the extreme step of forming a pool to handle all sinkhole claims.[14] For larger structures, where professional consultation is essential, sub-surface exploration is used to varying degree. While individual homeowners may or may not wish sinkhole insurance, at their option, the builders of major structures find the threat of sinkholes an unacceptable risk, and pay consultant fees, as a form of insurance in advance.

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*Neil Webb, Associate Director of Planning, University of Florida

Hazards to Equipment and Livestock

No specific compilations in this category could be found by this researcher, after extensive canvassing of insurance offices and relevant government agencies with responsibilities in the study area. Yet, these hazards are generally recognized to exist as past and present phenomena. Resort was then made to personal interviews with agricultural officials and farmers in the study area over a period of two years. These interviews constitute a series of field notes, and from these a synthesis has been made to outline the existing situation.

In the case of Levy County, a special project under the 1970 Agricultural Conservation Program was initiated by the Agricultural Stabilization and Soil Conservation Service Director, Mr. Frank Bullock, at the county seat, Bronson, Florida.* His recommendations resulted in federal funding for a program of filling sinkholes on farms on a cost-sharing basis, wherein up to 50 percent of the cost is paid by the ASCS, and with up to 80 percent payable in the case of low-income farmers. Certain of the justification offered for the program is quoted here because it sets forth official perception of the hazard and problem at the county committee levels.[15]

> If an individual is using one of these holes or other open land as a dump for his garbage, or if he is attempting to fill in one by means of old auto bodies or junked appliances; he is running the risk of poisoning not only his own family, but his neighbor's as well. At times the underground water level rises and dissolves the refuse that has been placed there, then subsides to continue its westward flow. If a

*Interview with Mr. Frank Bullock, Levy County Director, Agricultural Stabilization and Conservation Service, 1971.

> shallow well has been sunk in the path of this flow, it is highly probable that bits of garbage, metal, livestock droppings, and even pesticides could be dissolved in a family's supply of drinking water.

Citing the existence of a special problem affecting some 200 farms in Levy County, where "sinkholes fall into underground streams after heavy rains," Mr. Bullock stated that the holes prevent normal cultural operations and the grazing of livestock on crop and pasture land. The sinkholes also cause permanent damage to the land and accelerated erosion, if not properly treated. Filling of the sinkholes was recommended, with the estimate that some 100 of the 200 farms would use the practice if approved. It was estimated that the cost of filling the hole would vary from $5 to $30 per hole, and that among the conservation benefits to be derived, in addition to pollution prevention, would be rehabilitated farmland. The matter of pollution is a separate topic and will be amplified in a section which follows.

A press release in January of 1971, some 18 months later, reported that "there are many more sinkholes to be filled."[16] Only about twenty farmers had participated in the program, a low response in comparison to the size of the problem; and answers were sought in the field. In the Director's view, government programs already involve much of a farmer's time with paperwork, and the sinkhole project added to these demands. More important, however, was the fact that farmers had to fund half the costs, and the farmers in the study area, of which Levy County is representative, were already plagued by insufficient incomes. Thus, the farmers had to assign their funds to even higher-priority needs, and no cure for this problem is in sight. While Levy County's experience

has been cited here, the sinkhole problem exists over much of the entire study area.

From the interviews with farmers, this picture emerges. Sinkholes are treated when they become enough of a threat to require some form of attention. One farmer plowing a 60-acre field for row crops described a chimney two feet wide and twelve feet deep which had opened up as his tractor passed over it.* His reaction was to be grateful that neither he nor his tractor had fallen in, the hole being centered exactly under the machine. He then marked the hole with a limb, and continued plowing. Four other similarly marked new holes were noted within the space of an acre. Other important parts of the 60-acre rectangle were unused and in brush. These were the sites of both outcrops and sinkhole concentrations. Other farmers, when asked about sinkholes opening when heavy equipment was in use, said simply that they "looked out for it". All farmers interviewed either had had similar experiences, or were familiar with those of others.

Livestock losses are not recorded, but are considered to be common. One of the farmers who was a participant in the Levy County filling program had contributed $1500 as his half of the project.** His farm has lost 32 hogs in sinkholes over a period of years. Ongoing losses of individual hogs, cows and calves were common knowledge to all farmers questioned. The photograph of the Brahma calf stranded in a small sinkhole, Figure 18, was taken by the writer during one of the field trips. The animal was alone in a large pasture and its survival without water could not have

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* Mr. Claude Sache, Levy County farmer
**Mr. Vance Watson, Levy County farmer

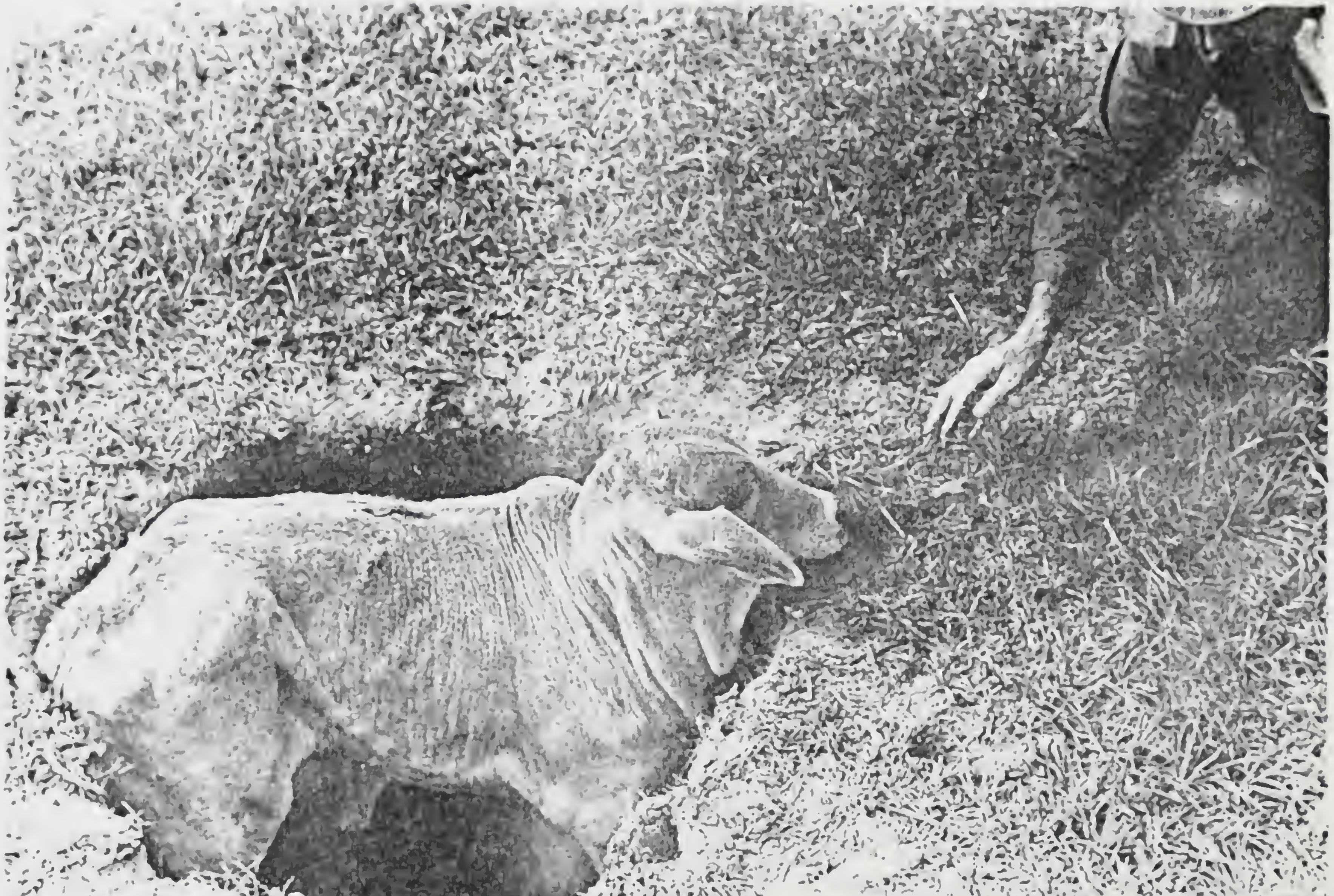

Figure 18 -- Accepted Risk With Livestock, Hazard to Animals on Highway 320 East of Chiefland

been of long duration. The farm owner was notified and the incident accepted matter-of-factly and routinely, although Brahma calves are valuable animals. The point is made that the sinkhole hazard to livestock is accepted as part of the operation, no more and no less.

Another farmer in Levy County, whose pastures contain dozens of small chimneys stated that they lost cattle because of broken legs (most chimneys were on the order of 6 inches across at the surface), and when asked if the slowly grazing animals could not avoid the holes, said, "Yes, until they get to playing."* Again, the point is made that sinkhole losses, while regretted, are tolerated unless they get too high. As has been noted elsewhere, the usual home remedy is to fill in with rock, or anything else, including pollutants, or to fence around, or at least to "post". In the case of the small chimneys none of these solutions was feasible. The entire pasture was fenced around and an adjoining borrow pit was fenced off, but the individual holes were too numerous, and the pasture had to be used, if at all, subject to occasional calf losses.

The foregoing represent a good sampling of the numerous incidents discussed and observations made in the study area. In the judgment of this student, they reflect a pattern. Karst hazards are a direct threat to equipment and to livestock. Adjustments are made according to the scale of the threat, and vary from "posting" a dangerous hole, to filling in various ways, to fencing off an area and working around it, to filling

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* Mr. Fred Giglia, Levy County Farmer

with federal help, to the acceptance of livestock losses, to the complete abandonment of portions of the land.

Hazards to Humans - Pollution

In addition to the accidental threat to men who are operating machinery around collapsible ground, there is a more pervasive and large scale hazard in the spread of pollutants which is made possible by the subsurface movement of water in karst terrane, and its accessibility to humans from the surface.

In the Levy County sinkhole-filling program referred to in the preceding section conservation gains were cited as one of the benefits. Another objective was the control of pollutants. The problem was described for Levy County's purposes as one where sinkholes open into underground streams after heavy rains. When not properly filled, their presence usually results in the contamination of underground water which, in most cases, is used on the same farms or nearby towns for drinking water and eventually ends up in springs or rivers.[17]

The pollution problem is not of course limited to the 200 affected farms of Levy County. It applies to most of the farms and population centers of the entire study area.

The distribution of the farms and centers throughout the study area defines the geographical breadth of the problem, and the size of the population center adds proportionately to the intensity. Gainesville is the largest center, is in the highest vulnerability category, and has a water pollution problem, which has been an object of sharp controversy for years. The problem is well documented and needs only passing reference here to illuminate the point.

For a number of years the University of Florida has disposed of its sewage effluent into Lake Alice, a karst feature, on the west side of the campus, in an area of Eocene outcrop. The lake averages 100 acres in area, without natural outlets, and the sewage effluent is from 15 to 25 millions of gallons per day.[18] To this is added 12 million gallons per day of thermally polluted water from the University Health Center's steam plant, so that 27 to 37 mgd are poured into the lake. Most of this is channeled out through two deep 24-inch wells which drain into the Floridan aquifer below. As the city of Gainesville's population increased in the 1950's, and increasing demands were made upon the city's well fields, several instances of pollution of the fields were noted. One isotope spill from the University Medical Center reportedly traveled the five miles to the well fields in just ten hours. As this is written, the problem still awaits solution.[19]

Part of the problem of pollution is the need for officials to dispose of the daily sewage of an increasing population by using the means at hand, rather than waiting on other events. Again in the Gainesville area, in 1972, the city government had proposed the use of the Kanapaha Lake and Haile Sink area (southwest of Lake Alice, in the Eocene outcrop region) as a site for a sewage treatment plant and the discharge of 5 million GPD down the sink. The proposal was resisted by knowledgeable scientists in the university community, one of whom reminded the city government that:

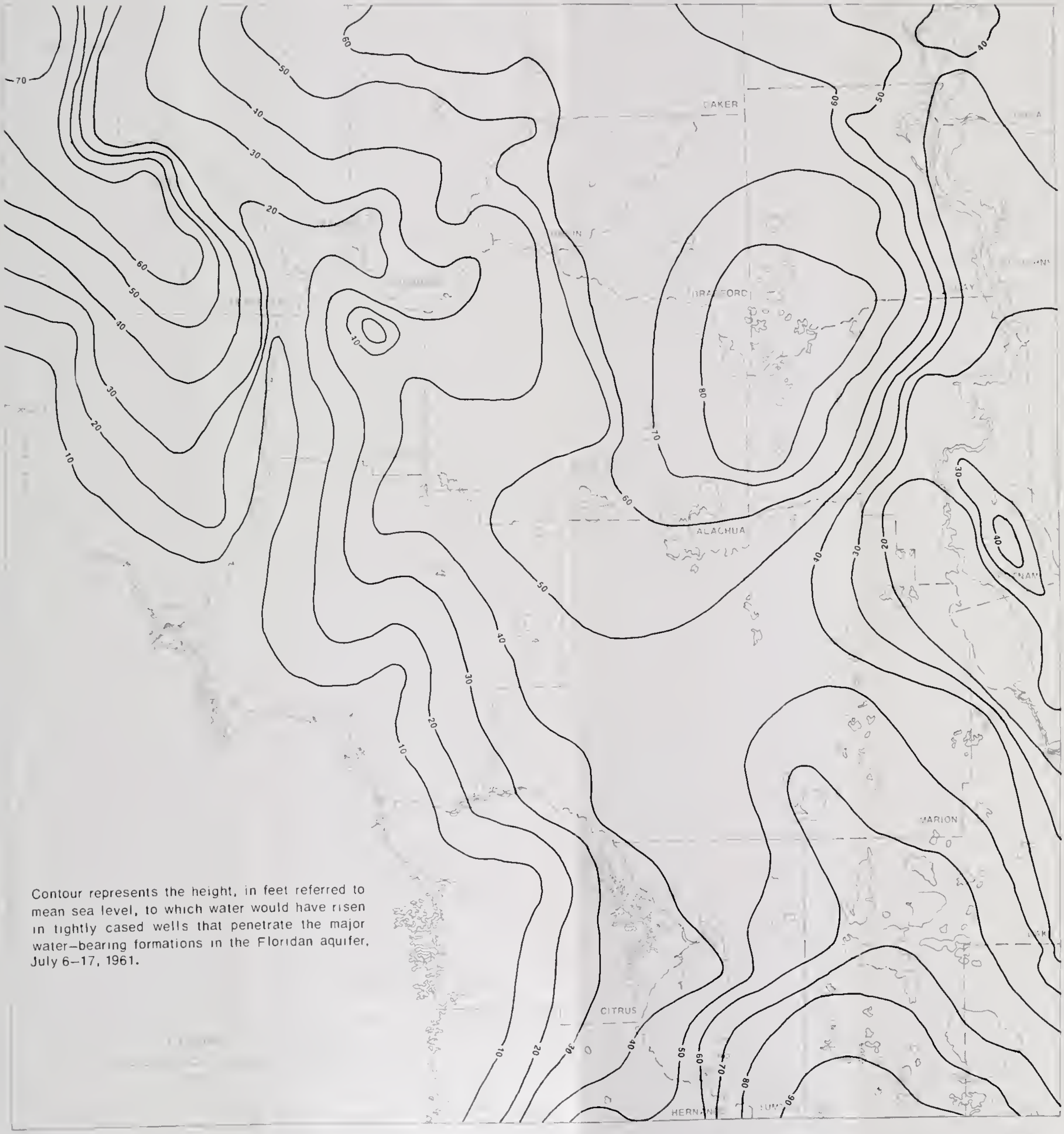
> The past history of ground water pollution in Gainesville should be warning enough as to the wisdom of careful study. The best available

> evidence indicates all the groundwater pollution in the Gainesville area in recent years has been caused by the introduction of sewage effluent down sinks or through injection wells. These are the methods suggested as modes for disposal of effluent in the Kanapaha Lake and Haile Sink area.[20]

In March, 1972, The Alachua County Health Department stated that 16 percent of the wells in the county were polluted, up from 11 percent in 1969. This is an increase of 40 percent in three years.[21] From the foregoing it is clear that on the institutional level, the university's and city's pollutants threaten both the city's well fields, and the Floridan aquifer, while on an individual, as opposed to an institutional level, some one well in six in private ownership has already become polluted. Fortunately, directional movement of underground water is 'away from' larger population centers. Map 11 shows the piezometric surface along which ground water moves across the contours from higher to lower pressure levels. This is more important regionally than locally, however, but it is a vital part of future planning projects.

Returning to the rural portions of the study area now, the major importance of the pollution threat is the wide area of its distribution. All farms with sinkholes which communicate with underground streams are potential sources of pollution. This is because of the traditional use of sinkholes on farms as refuse pits. Garbage, rubbish, trash of all kinds, and even dead animals are frequently disposed of in sinkholes. An educational program is in effect in several of the counties, but their degree of success is uncertain. An example is that of the Levy County Rural Area Development Council, which prepares and circulates

# PIEZOMETRIC SURFACE




Map 11

brochures to urge residents to dispose of all refuse at county landfill sites. County Health Officers likewise advocate hygienic measures, again with only piecemeal results. Throughout this observer's visits in the field, the sight of sinkholes as refuse pits was commonplace. The writer holds the view that the public health situation will have to get worse before it starts getting better, because even on large, prosperous farms, the bodies of hogs, dogs and calves could be seen in sinkholes located near the farmhouses. The pollution hazard directly attributable to karst features may well be likened to those events which Burton and Kates term, "Today's acts of God, becoming tomorrow's acts of criminal negligence."[22] Responsible county officials in many departments are persistent in their educational efforts here, as are the schools.

<u>Hazards to Humans - Springs</u>

The topic of springs in karst terrane has a number of facets. The thrust of this chapter on hazards is on the negative aspects, so this section will deal with the special hazards to human life posed by the presence of the many karst springs. The springs and their surface outlets, called "runs" in the local area, are particularly attractive for recreation, and have been so regarded since the earliest settlement. The frequent discovery of Indian artifacts at ancient levels also attests to the antiquity of this appeal to man. In recent years, as scuba diving has become popular, there has been also an increasing toll of human life under the waters. A large share of the karst springs of Florida are in and near the study area, and these have been the sites of an equally large number of the diving deaths. A sampling of recent newspaper briefs is listed here:

CAVE DIVER JOINS BROTHER IN DEATH[23]

Brooksville, Florida. A recovery team has found the body of 26-year-old diver Randy Hilton, who drowned in a 300-foot deep sinkhole 10 years after his brother died while exploring another underwater cave system. (Larry Hilton drowned near High Springs, Alachua County, 10 years ago.)

THREE DIVERS DROWN IN LITTLE RIVER SPRINGS[24]

Live Oak, Florida. Three young men from New Jersey died while diving here Sunday, Sheriff J. M. Phillips reported.

3 CAVE DIVERS DROWN IN SPRING[25]

Marianna, Florida. Three men from a Columbus, Georgia, skin diving club drowned Saturday in an underwater cave near this Jackson County town.

The National Observer followed up on the deaths at Little River Springs with a general comment on the appeal of the Florida springs:[26]

> Cave divers consider the Florida springs area the best place in the world to practice their sport. The springs bubble from a vast network of underground streams at an exact 72 degrees. It's ideal for diving because of the water's extraordinary clarity, and the endless tunnels offer a cornucopia of marine delights: fossils, Indian relics, and glimpses of breath-taking natural architecture.
>
> But because cave divers cannot surface quickly if they get into trouble, they are encouraged to take precautions that are thought to be unnecessary for open-water diving.
>
> Cave diving, safe though it may be for experienced divers, has unique risks. Since 1960, according to the Florida-based National Association for Cave Diving, 180 divers have died in Florida or off its coast. Of these, 90 died in caves--and 16, including the 3 New Jersey men, died in Little River Springs.

It is clear that the springs and their underwater feeder streams and galleries have a special appeal, and are a special hazard for whatever reason, to modern scuba divers.

<u>Hazards and Problems for Highways</u>

The Department of Transportation (or State Road Department) has a variety of problems concerning sinkholes. (See Figure 19). The major effort is directed toward prevention and minimization of hazards where DOT responsibility is concerned. The types of problems that may arise are categorized as follows:

(1) sinkholes may be encountered on construction sites and must be filled before paving can be completed;

(2) sinkhole "drop-out" may occur during construction, constituting hazard to men and equipment;

(3) surface subsidence may crack or otherwise damage roads;

(4) bridge foundations may be affected by subsidence.

These are real problems that occur statewide but are often more pronounced in areas where limestone is very near the surface.

Records in the files of the Research and Testing Divisions of the Florida Department of Transportation show that the agency has dealt with hundreds of hazards and problems of all four kinds listed. Extensive research has been carried out, particularly in regard to bridge locations in "sinkhole-prone" areas.

Numerous examples of sinkhole problems are recorded, of which a high percentage occur in the Eocene outcrop area. Special sinkhole report forms are filed for each reported sinkhole. The Highway Maintenance Department receives the initial notice; they in turn alert the Research

Figure 19 -- Sinkhole Damage to Highways: Courtesy DOT.

Division who dispatch a geologist and other specialists to the site. Printed forms include the following standardized items of information:

| | |
|---|---|
| County | ________ |
| Road # | ________ |
| Date | ________ |
| Diameter | ________ |
| Depth | ________ |
| Township | ________ |
| Range | ________ |
| Section | ________ |
| Comments | ________ |

The item "comments" often contains subjective descriptive notes concerning the sinkhole. There is usually a diagram and often photographs attached to the report form. In some cases special reports are filed by the geologist after extensive studies have been made. Evidently the breadth and extent of the reports are in direct proportion to the seriousness of the individual situation. Dozens of minor sinkholes are only mentioned in the one standard report, whereas research in depth has been carried out on troublesome areas.

U. S. 19 and 98 (also S. R. 55) through Chiefland has long been an area where road construction crews were hampered by sinkholes. Some caved in precipitously, while others were already present in the limestone terrane. The sinkhole problems were solved individually as the situation warranted. Table 11 contains a tabulation of some of the methods used to close the voids in pavement or in right-of-way land.

Table 11 Procedures and Comments on Specific Sinkhole Problems Encountered by the Department of Transportation

| Dimensions* (Diameter and Depth) | Procedure | Comments |
|---|---|---|
| 7' x 3' | Clean out the sinkhole, to some depth, by means of a dragline;<br>Place riprap, such as broken pieces of concrete pavement, in the bottom of the excavation;<br>Place cross ties, some sort of metal poles or rails, on top of the riprap;<br>Place a layer of dry cement, consisting of a mixture of 3 bags of sand to 1 of cement, on top of the cross ties;<br>Backfill and compact suitable fill material;<br>Place and compact a one foot thick layer of limerock subbase; and<br>Patch the pavement. | Follow 3" rain. |
| 2' x 3' | Patched with sand-clay and sand-asphalt cold mix, three times, but continues to settle at rate of 2" to 4" per week. | Considerable difficulty with sink-holes in this area in the past. |
| NA | Fill the hole with limerock or suitable material to a point 17" - 20" below the surface. Then pour 10" - 12" cement to seal the rock. Complete the job by filling and packing with suitable material. | Geology section will investigate further as soon as possible. |

| | | |
|---|---|---|
| 3 x 22 | Cap the hole with a 9" thick concrete slab, using 5/8" reinforcement steel. The cap would be placed on the hole after filling it with either clay or limerock. | Will probably drill the area later. |
| 4 holes (size not given) | Fill the top portion of each hole in the limestone with a soil-cement mixture. This will prevent the surficial materials from being carried down into these solution's features. | It is recommended that a portion of the shoulder and ditch be treated with soil-cement to insure that no subsidence will occur. |
| 10 x 5 (plus a 40-50 foot crack in the same area) | NA | Coring revealed that the area in question is perforated with small voids. We find no practical means of assuring ourselves that the fill will be stable. |
| 5 sinkholes (2 old and 3 new) | Recommend that active area be bridged, supported by piling rather than footings. | It would also be best if the additional load of the piling and bridging not be supported by rock directly over the large cavity. This could be accomplished by: 1) Driving piling through the cavity to the bottom of it and seated in the rock, or 2) Shorter piling could be used and driven where drilling has shown the absence of cavities. |

*As stated in DOT reports

Table 11, Continued

| | | |
|---|---|---|
| old "sink hole", solution feature, or fracture in the limestone | Currently filled with local material | The probability of collapse or surface sinking at this time seems small. |
| NA | Recommend that the design of the median and lateral ditches be such as to drain surface waters away from the roadway. An alternate solution would be moving the centerline of the proposed roadway southward several hundred feet to by-pass the sinkhole. | This particular sink seems to be relatively young, as indicated by its steep sides and characteristics of vegetation growing in and around it-drains a very small area. |
| NA | Recommend that the sink be filled and that drainage be directed away from it. | Caused by a combination of the rains saturating the sand and clay overburden increasing its weight, and the general low level of the ground water in the area. The ground water helps support the roofs of cavities and when this support is removed collapse is likely. |
| Several sinks of small diameter and rather deep (>20 feet) | Fill with rubble and boulders to within a few feet of the surface and then put progressively finer material on top. An alternate method would be to cap them with concrete after filling with rubble or boulders, however, this is more expensive. | We can hope to prevent loss of surface soils by using fill with a selective gradation, or to bridge the structure by cappings. |

| | | |
|---|---|---|
| 8 x 4 12 x 8<br>12 x 10 1 - 6<br>10 x 5 3 x 21<br>5 x 5 8 x 2<br>25 x ? 25 x 10<br>15 x 16 4 x 3<br>8 x 7 | Take steps to backfill these holes. | Sketches enclosed. |
| 5' diameter<br>6' diameter | Holes excavated, backfilled with boulders, placed reinforcing steel and poured 9" thick concrete cap over sinkholes. | 32 to 36 feet left of center-line of roadway. |
| 1,673.20 sq.ft. | Concrete cap | Excavated, back-filled with boulders, reinforcing steel, concrete cap. |
| 369.92 sq.ft. | Concrete cap | |
| 589.68 sq.ft. | Concrete cap | |
| several sinkholes | Filled with limerock boulders | Between edge of pavement are ditch pavement, under and behind ditch pavement. |
| NA | 6 x 9' concrete slab placed | 20 feet right of center-line |
| 10-13 holes | Capped with one solid cap | Fill in during construction |

Table 11,Continued

| | | |
|---|---|---|
| 532.85 sq.ft. | Concrete cap | Sinking pavement |
| small hole | Patched with asphaltic concrete pavement | At edge of pavement |
| 2 sinkholes in pavement | Maintenance crew "patched" the sinkholes | No record kept of dates or exact location of these holes. |
| several sinkholes in right ditch | Filled with dirt when the job was dressed out. | No records were kept of the locations or sizes of these holes. |
| 3 sinks: 6 x 6, 3 x 3, 3 x 6 | Fieldstone, fill material, and plant mix | NA |
| 2 sinks: 3 x 3, 4 x 4 | Fieldstone, sand cement, fill material and plant mix | NA |
| 3 x 4 | Same as above | NA |
| 2 sinks: 4 x 6, 4 x 4 | Unrepaired - existing | NA |
| 3 sinks: 3 x 6, 2 x 3, 3 x 3 | Fieldstone, fill material and sod around ditch pavement | NA |

| | | |
|---|---|---|
| 4 x 12 | NA | Solution well has several holes at surface, but are bridged between with soil. |
| 4 x 4 | NA | Sink occurred after heavy rainfall |
| 5 x 2.5' | Filled by maintenance the following morning | Flambeaus placed along edge of pavement for night. |
| 3 x 4 | NA | Have had 3 sinkholes in 50' radius in past 6 months. |

The emphasis at the present time in the Department of Transportation is on research, but maintenance operations are routine and continuous. Figure 20 shows a typical small filled hole by the roadside. Mr. Lloyd Burlson, Director of Maintenance for several counties, estimated that the cost of filling holes is approximately $1.50 per cubic yard of void space. This figure represented an overall average for repair costs on existing highways and roads. Relatively speaking, not many sinkholes open up under the pavement itself, but those in the right-of-way areas are fairly common.

The reports were not uniform despite the format available. In many cases the sizes of the sinkholes were not given at all. Most of the data included procedures used or recommended and also comments containing additional information about the situation. The notes were informative and interesting but were generally unscientific in presentation. Special studies by the geologists assigned to certain problem-areas were systematic and well-presented.

The engineering geology section of the Department of Transportation has given attention to the problem of being able to anticipate and locate geologic conditions which will cause trouble in construction, especially sinkholes and caverns. Existing sinkholes or those geologic features which have a surface expression are easily located and mapped. They can often be seen on air photos of the area. Those features, such as caverns, which do not have a surface expression are not so easily located. Their existence may be inferred but mapping is difficult if not impossible. In addition, it is also difficult to estimate the effect of these conditions, if any, on construction.

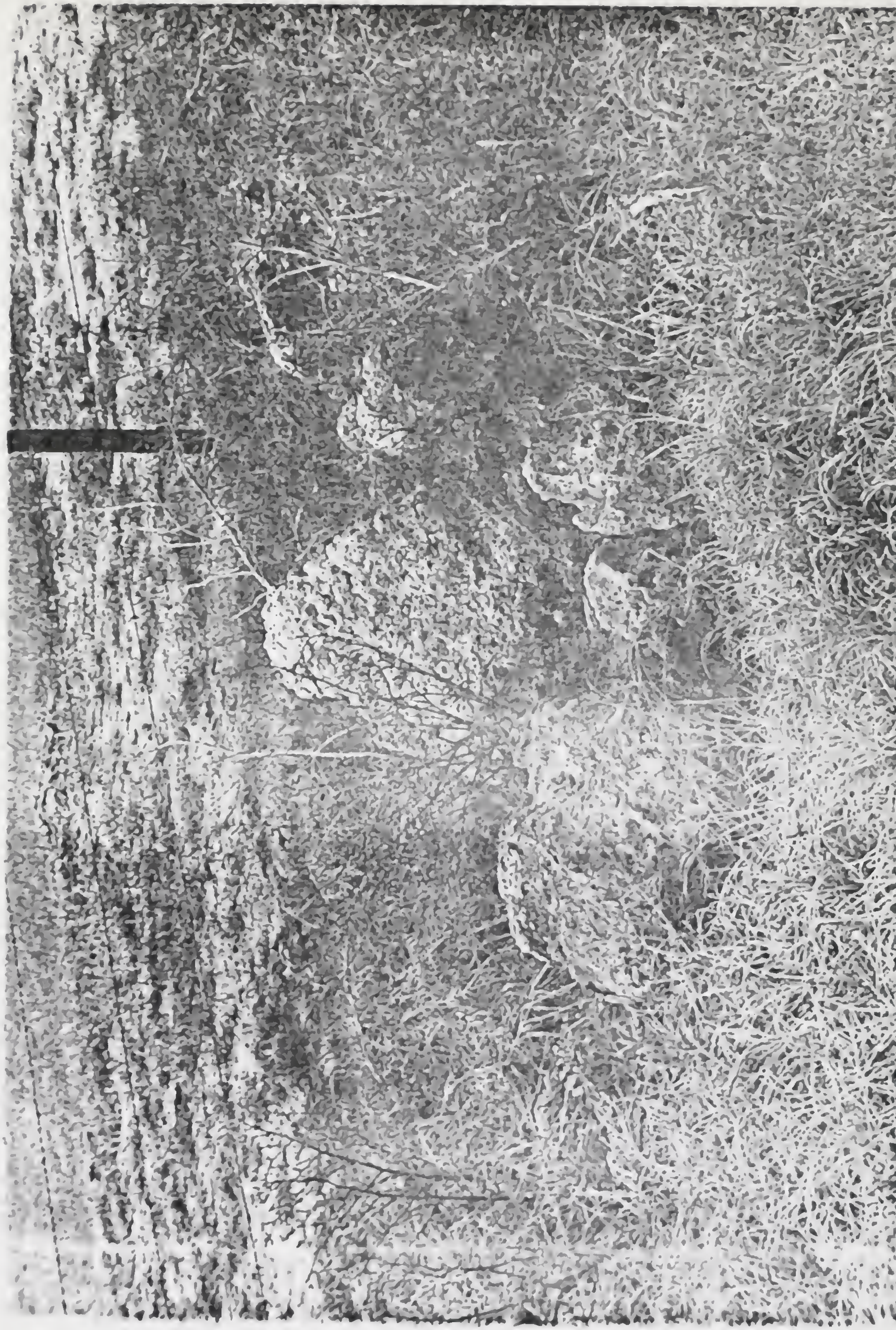


Figure 20 -- Limerock Boulders Used to Fill Small Roadside Sinkhole near Chiefland

Numerous experiments have been carried out by the Department of Transportation in Tallahassee in which infra-red imagery and other remote sensing techniques were employed in an attempt to map muck and sink areas. Only limited success was achieved and work is still being done. S. H. Griffis, geologist, prepared a report correlating the infra-red imagery remote sensing methods with conventional stereo-pair methods of interpretation.[27] The conclusions were as follows:

1. DOT stereo pairs show considerably more sink features than remote sensing photography in the report.

2. Some surface or near surface rock that was located by remote sensing was undetected on stereo pairs.

3. Some surface rock that was detectable in DOT stereo pairs was not located by remote sensing.

4. Most of the areas designated as active muck are merely drainage features which retain moisture.

The infra-red and other types of differential selective photography are techniques which show promise as tools for the Department of Transportation, but on the particular projects compared, regular stereo pairs showed more karst features.

Much of the current budget of time and money of the Research Division is allocated to the Bridge Boring Program. Collapse of a highway bridge in West Virginia in 1967 and subsequent failure of a structure over the Anclote River in Florida prompted the state legislature to pass a law requiring regular inspection of bridge foundations. Section 1 of Senate Bill No. 177 states as follows:

> Prior to July 1, 1970, and prior to January 1 of each fifth year thereafter, the State Road Department shall make a thorough engineering inspection of each bridge or other

> structure on all state-maintained systems of roads and highways in this state as to the structural soundness thereof and as to the safety thereof for the passage of vehicular traffic thereon. The State Road Department shall also devise and implement a program of subsurface soils exploration to ascertain the adequacy of foundation bearing for all structures in sinkhole prone areas of the state.

The responsibility for accomplishing the work required by the state law was given to the Department of Transportation Materials and Research Office located in Gainesville. The office has developed a program to obtain equipment and staff and is proceding with the work. The object is to determine which structures might fail because of foundations falling into cavities or sinkholes.

The only map of "sinkhole-prone" areas in existence is that of Vernon discussed earlier in connection with sinkhole insurance. Criteria for the map were primarily economic in order to estimate possible damage to structures. The map is unsuitable for the assignment of bridge inspection but is being used.

The hazards of sinkholes are being recognized by public agencies and legislation has been enacted; however, there is not always an efficient method to use to solve the problem. It is important that work is being done to lessen hazards, but it is disturbing to note that the means are inadequate for the task. Perhaps a compromise will come with an effective and economical program in the future.

## NOTES TO CHAPTER V

[1] Ian Burton and Robert W. Kates, "The Perception of Natural Hazards in Resource Management" (Reprinted from *Natural Resources Journal*, Vol. 3, No. 3, Jan. 1964).

[2] *Ibid.*

[3] *Ibid.*, p. 438.

[4] *Ibid.*, p. 424.

[5] *Ibid.*, p. 415.

[6] Kenneth Hewett and Ian Burton, *The Hazardousness of a Place* (Toronto: University of Toronto Press, 1971), p. 5.

[7] *Ibid.*, p. 6.

[8] *Ibid.*, p. 13.

[9] Robert O. Vernon, *Report to the Legislature, Sinkhole Probability*, Florida State Geological Survey (1969).

[10] Florida Legislature, Senate Bill No. 1106, Hearing Relative to Implementation, transcribed in full (July 2, 1969).

[11] *The Gainesville Sun* (Jan. 23, 1972).

[12] Florida State Treasurer's Office, Bulletin No. 453 (Implementation of SB-1106, June 16, 1969), pp. 30-31.

[13] Environmental Engineering, Inc., "Report on Building Foundation's Suitability," Gainesville (Sept. 4, 1972).

[14] Florida, State Treasurer's Office, pp. 35-38.

[15] Levy County Agricultural Stabilization and Conservation Service, pamphlet, Pollution in Levy County (1970).

[16] The Florida Times-Union (Jan. 29, 1971).

[17] Agricultural Stabilization and Conservation Service, Agricultural Conservation Program Proposal (June, 1969).

[18] James H. Cason, "Lake Alice--A Study of Potential Pollution of the Florida Aquifer," The Compass of Sigma Gamma Epsilon, Vol. 47, No. 4 (May, 1970), p. 207.

[19] Ibid., p. 210.

[20] Center for Water Resources Research, "Comments on Lake Kanapaha Sewage Treatment Environmental Assessment Station" (May, 1972), p. 2.

[21] The Gainesville Sun (March 6, 1972).

[22] Burton and Kates, "The Perception of Natural Hazards in Resource Management," p. 414.

[23] The Gainesville Sun (March 10, 1972).

[24] Ibid. (Sept. 13, 1972).

[25] Ibid. (Sept. 17, 1972).

[26] The National Observer (Sept. 16, 1972).

[27] S. H. Griffis, "Correlation Between the Remote Sensing Method Aerial Photography and Stereo Pair Method of Aerial Photography," Florida State Department of Transportation, Geology Section (April, 1970), p. 3.

# CHAPTER VI

## LIMESTONE AS A RESOURCE

Historically, the West Central Florida area has used its natural and human resources first for subsistence farming, or for stock raising, then for the extraction of forest products, and finally it has used its minerals. Farming has supported a small, stable population from the beginnings of settlement after the close of the Second Seminole War (1842), to the present. The forest products industry has seen several mild booms and busts, starting with the last quarter of the 19th century, when the virgin forests were first logged or turpentined. Large commercial forests and family-owned tree farms characterize the industry today, and these too have levelled off along with modern practices in reforestation and sustained-yield tree farming. The great bulk of the forest production ends up as wood pulp, and pulp producers strive for stability and the avoidance of peaks and valleys in their production flow. This makes for stability of the labor force and so helps to keep population figures from increasing. Rural young people entering the labor market in areas where nonfarm employment is limited, i.e., does not increase, have to go elsewhere for jobs. Finally, mineral products in the Eocene outcrop area have furnished intermittent nonfarm wage employment to several generations of the population. These mineral products have been limestone as a building rock and for road bases, dolomite for use in fertilizers, and phosphates with a broad range of applications.

These minerals thus can be placed in proper perspective as one of a number of natural resources used in turn as they became marketable, with each placing its cachet in part on the land and economic base of the outcrop areas.

Limerock

Florida as part of the Coastal Plain Province is composed of sedimentary rock and nonindurated materials of various grain sizes. Limerock underlies the entire platform, with various thicknesses of overburden existing from place to place. As has been described, irregularities and movements in the basement rocks produced the Ocala Arch. Subsequent erosion exposed the Eocene rocks at the surface approximately along the axis of the Ocala Uplift. The limestone immediately at the surface facilitated mining and as uses were found, an industry was established.

Principal minerals in the study area are limestone, dolomite, and phosphates. All have had an impact on the settlement and development of the area. Probably the most striking effects have been from the mining of phosphate, which is described here with limestone and dolomite. The regional picture of mining as it affects the landscape must include phosphate, which (though not a carbonate rock) is found in very close association. Mining of limerock has been continuous for eighty years and is still important in the economy of several counties in the study area.

Robert S. Wood in 1957 devised a graph showing "Functions and Uses of Limestone." The information contained in this graph is summarized

in Table 12.[1] Florida limerock is not presently used in all these ways, but is suitable for such use in almost every case.

Stone was an important part of the state's nonmetal mineral production in 1970, with phosphate rock, stone, cement, sand and gravel, and clays amounting to 93 percent of the total.[2] Limerock is used as stone, usually crushed. In 1970 the industry's receipts increased 3 percent over the 1969 values, but the tonnage mined remained stable. Output came from 90 quarries in 23 counties and the highest use was for road base, with concrete aggregate being the next highest specific use.[3] In the study area the mining of limerock is a viable industry influencing the appearance of the landscape. According to a tabulation in the Minerals Handbook, 1970, Alachua County has six quarries, Levy County three, Marion County ten, and Sumter County three. Citrus County is included in a group of eight counties with nineteen quarries and is estimated to have three to five.* These figures represent quarries presently in operation and producing fairly regularly. Evidence exists, in the form of abandoned pits, of much mining activity in the past.

For the most part the limestone in the study area is of very high grade reaching a minimum of 95 percent calcium carbonate. In many instances it is much purer, up to a maximum of 99.8 percent $Ca\ Co_3$. Its largest use is for road construction and it is sold in truckloads by mining companies for $1.00 per ton for this purpose. There is a good market, in and near central Florida, for the very pure limerock con-

*Jim Moore, Dixie Limerock and Cement Company, Reddick, Florida

Table 12 Functions and Uses of Limestone

A. Raw Material

1. Rubber
2. Concrete
3. Stock Feeds
4. Calcium Cyanamid
5. Agriculture (Liming)
6. Synthetic Whiting
7. Calcium Carbide
8. Insecticides
9. Abrasives
10. Glass

B. Neutralization

1. Gasoline
2. Citric Acid
3. Water Treatment
4. Wood Distillation
5. Sewage Treatment
6. Calcium Phosphates
7. Metal Pickling Wastes
8. Explosives Wastes
9. Chrome Chemicals
10. Fine Chemicals
11. Dyestuff

C. Bonding Agent

1. Mortars
2. Plasters
3. Asphalt Paving
4. Insulation Materials
5. Road Soil Stablization
6. Sand-Lime Brick
7. Silica Brick
8. Stuccos

D. Flocculation

1. Sugar
2. Ore Flotation
3. Industrial Waste Treatment
4. Water Purification
5. Salt Processing
6. Paint Pigments

E. Solvent

1. Gelatin
2. Animal Glue
3. Leather (dehairing)
4. Casein Paints
5. Strawboard

F. Hydrolization

1. Soap
2. Pulp Cloth
3. Lubricating Grease
4. Organic Chemicals
5. Ammonia

G. Flux

1. Alumina
2. Open Hearth Steel
3. Electric Furnace Steel
4. NonFerrous Metals

H. Dehydration

1. Air Drying
2. Petroleum
3. Other Organic Solvents
4. Alcohols

I. Absorption

1. Bleaches
2. Gas Purification
3. Sulfite Pulp

J. Lubricant

1. Oil-Well Muds
2. Wire Drawing

K. Causticization

1. Caustic Soda
2. Soda and Sulfate Pulp

Source: Wood, 1958

taining no more than 5 percent of impurities such as sand and clay. There is an imaginary line across the State from east to west called by mining companies "the Blue Line," north of which the high grade limerock must be used for roads.[4*] The line goes through Polk County, well south of the study area. Occasional freezes north of this boundary expand the water in the roadway held by the clay and sand and cause cracking. Thus demand is enhanced for the highgrade rock produced in the study area to be shipped south from counties of Marion, Sumter, Levy, and Citrus.

Granulated stone is also exported, chiefly in 70-ton hopper cars rather than by trucks. The super fine grade is used as mineral filler material, mostly for asphalt. The second finest grade is sold to make asbestos shingles, and the coarsest grade is utilized by a glass manufacturer in Tampa, Florida.[**] Clearly road construction uses provide the primary market for limestone in Florida.

Cement manufacturing requires limestone, sand, and clay--all abundantly available in the west central counties. (See Map 12). "Hardrock" limestone found in Citrus County is utilized for this purpose. Building material dealers, concrete products manufacturers, ready-mix concrete manufacturers, highway contractors, government agencies, and miscellaneous applications consumed the cement produced in Florida in 1970. This state ranks third in the nation, after California and Texas, in consumption of cement.

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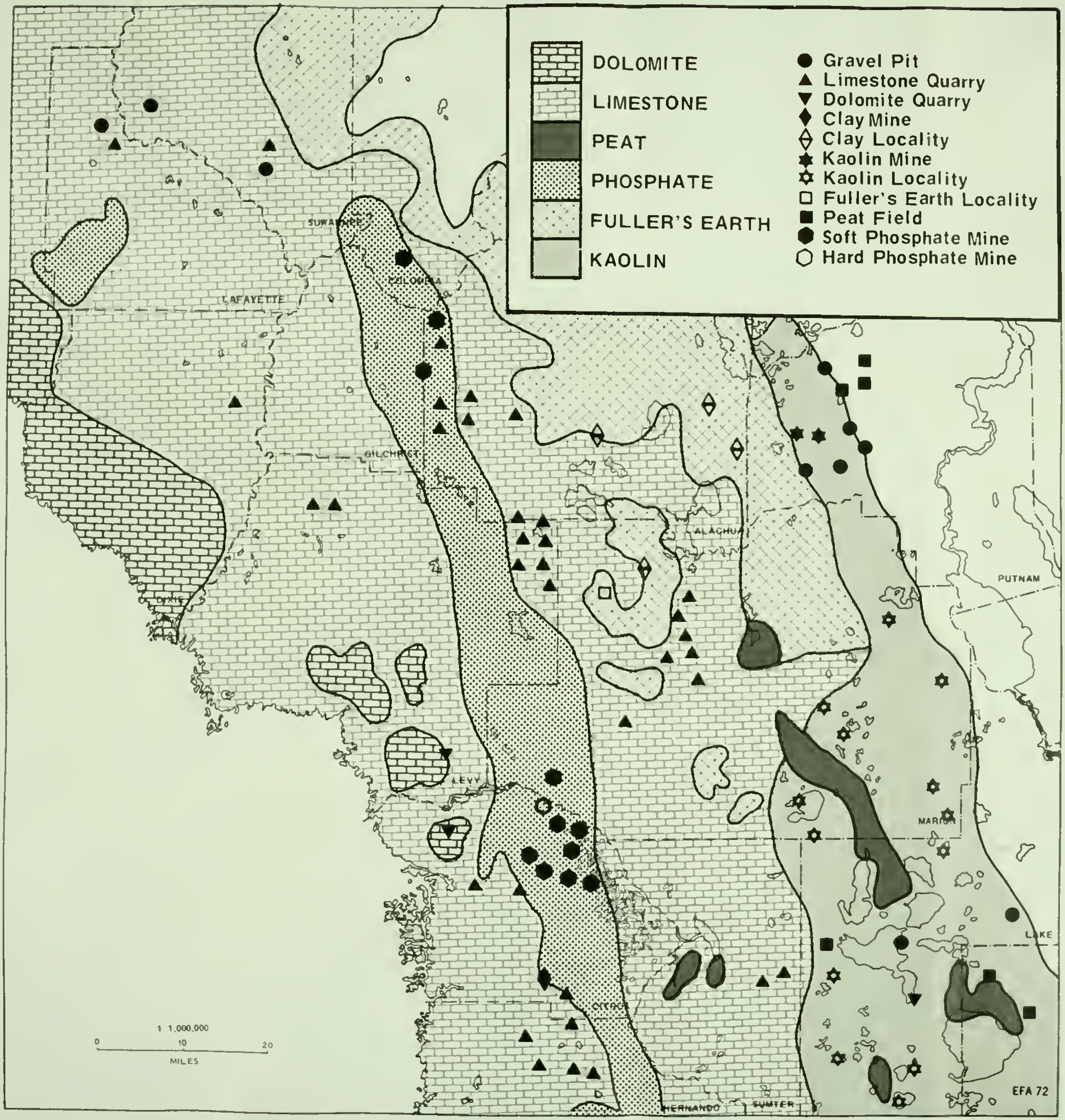
*Jim Moore.

**_Ibid._

## MINERAL RESOURCES




Map 12

Source: Claver–Mineral Resources And Industries Of Florida

Comparatively small amounts of limestone are used in agriculture to adjust soil acidity and to "build-up" the soil. Generally, dolomite is better suited for this purpose because its slower solubility is less injurious chemically to crops.

Quick lime is produced in the study area and is used in certain chemical operations, including the recovery of magnesia from sea water, production of pulp and paper, processing of food products, treatment of water supplies, and neutralization of wastes. The large Dixie Lime & Cement Company of Ocala operates a single quick-lime plant in Sumter County.

The many uses of limestone insure a future for the mining industry; however, problems exist with rising costs of production. The open pit method is used for Florida limerock mining. Overburden is removed and the surface cleaned of clay deposits. Figure 21 is a fairly unusual example of a cleaned surface especially interesting because of numerous solution pipes. Where the rock is above the groundwater level it is mined with bulldozers and loaders or draglines. It is possible to mine below the water level using the dragline. Often it is necessary to blast in order to loosen the rock for loading.

Limerock mining companies, such as Dixie Lime Company and Cummer Lime Company today hold rock leases from landowners. These are the lands which have been prospected and found to have limerock within ten feet of the surface. A small retainer is paid to the owner until mining might begin, at which time royalties are paid per ton extracted. The landscape which contains recoverable limerock is typically rolling and

Figure 21 — Cleared Limerock Surface Showing Numerous Solution Holes, Buda Pit Near Newberry: Courtesy DOT.

wooded. Hammock vegetation and sinkholes often indicate to prospective miners that the deposit is close to the surface. Early land users tended to leave the rocky exposures in woods and uncleared. It has been explained in an earlier section that rocky, sinkhole-filled hammocks were hardwood "islands" partially protected from fire.

## Dolomite

Dolomitic limestone resources are important in only two of the study area counties, Citrus and Levy. Vernon has mapped at least 75 square miles of dolomite in the two counties where there has been production intermittently since the 1930's.[5] Dolomite is a double carbonate of calcium and magnesium in which the magnesium carbonate constitutes about one-third. Accepted figures vary in amounts required for the mineral to be termed "true" dolomite.

The dolomite of the study area is a tan to brown rock, very porous, soft and friable, and is Eocene in age as are the limestones just described here. The rock is deposited in thin beds loosely cemented and is mined by open pit methods as is limestone. Most of the rock is below the high water table of the two coastal counties where it is found, and it is most often mined by dragline. Two companies, one in each county, are mining at the present time. Several companies have operated in past years when a value was placed on magnesium extracted from the rock. Today the principal use of the dolomite is for agriculture. Limestone is added to soils as a conditioner and as a neutralizer for acids present. Magnesium limestone, however, is better suited for this purpose because it does not damage crops by its appli-

cation.[6] Dolomite is used as a filler for fertilizers also, especially in the case of certain types that tend to be acid in reaction.

There are numerous uses other than those agricultural for dolomite, but none are developed at the present time for the Florida rocks. There have been several industries operating in the past to produce rock wool and to extract magnesium, but none are functioning today. The rock is considered unsuited for use in manufacturing glass or paper.

Prospecting and mining of dolomite began in the 1930's and so had little effect on settlement of the area. The industry employs only a few workers. The landscape with potential for dolomite mining is relatively high in elevation with the rock so close to the surface that it outcrops frequently.[7] Dolomite is dried, crushed, sacked, and loaded into boxcars or trucks for shipment to markets. Little change in the landscape is effected by the dolomite industry, but like limestone, it offers a contribution to the future economy which is likely to be of long duration.

<u>Phosphate</u>

Phosphates are included in the analysis of limestone as a resource because of the concurrent existence and similarity in methods of mining. Both have had an effect on settlement patterns and economy of the area, and it would be difficult if not impossible to attribute some particular cultural response to one or to the other. Phosphates had the most dramatic impact on the area and brought a measure of prosperity to the region. Limestone is still a viable resource today in the region, however, while phosphates are being mined generally farther southward.

Phosphates today account for the major part of Florida's mineral production value[8] and the state leads the nation's output. Agricultural uses accounted for 64 percent of production, industrial uses for 2 percent; and 34 percent is exported. The phosphates are used agriculturally in direct application to soils, as a component in stock and poultry feed, and as a filler for fertilizer. Industrial uses include the manufacture of elemental phosphorus.[9]

Phosphate rock is a general term that is given to any rock containing a significant amount of phosphorus. Physically and chemically the Florida phosphate conforms to the formula definition of the mineral apatite. It occurs in the Hawthorne deposits of Miocene age in the study area and is locally concentrated in depressions in the Eocene limestone surface. It also encrusts the pinnacles of the rough and irregular erosion surface now buried by younger deposits. The ancient sinkhole-filled karrenfeld topography became the repository for the phosphate ore accumulation. Vernon suggests that the northwest-southeast trending deposits occupy the crest of the Ocala uplift where faulting and jointing have been prominent.[10]

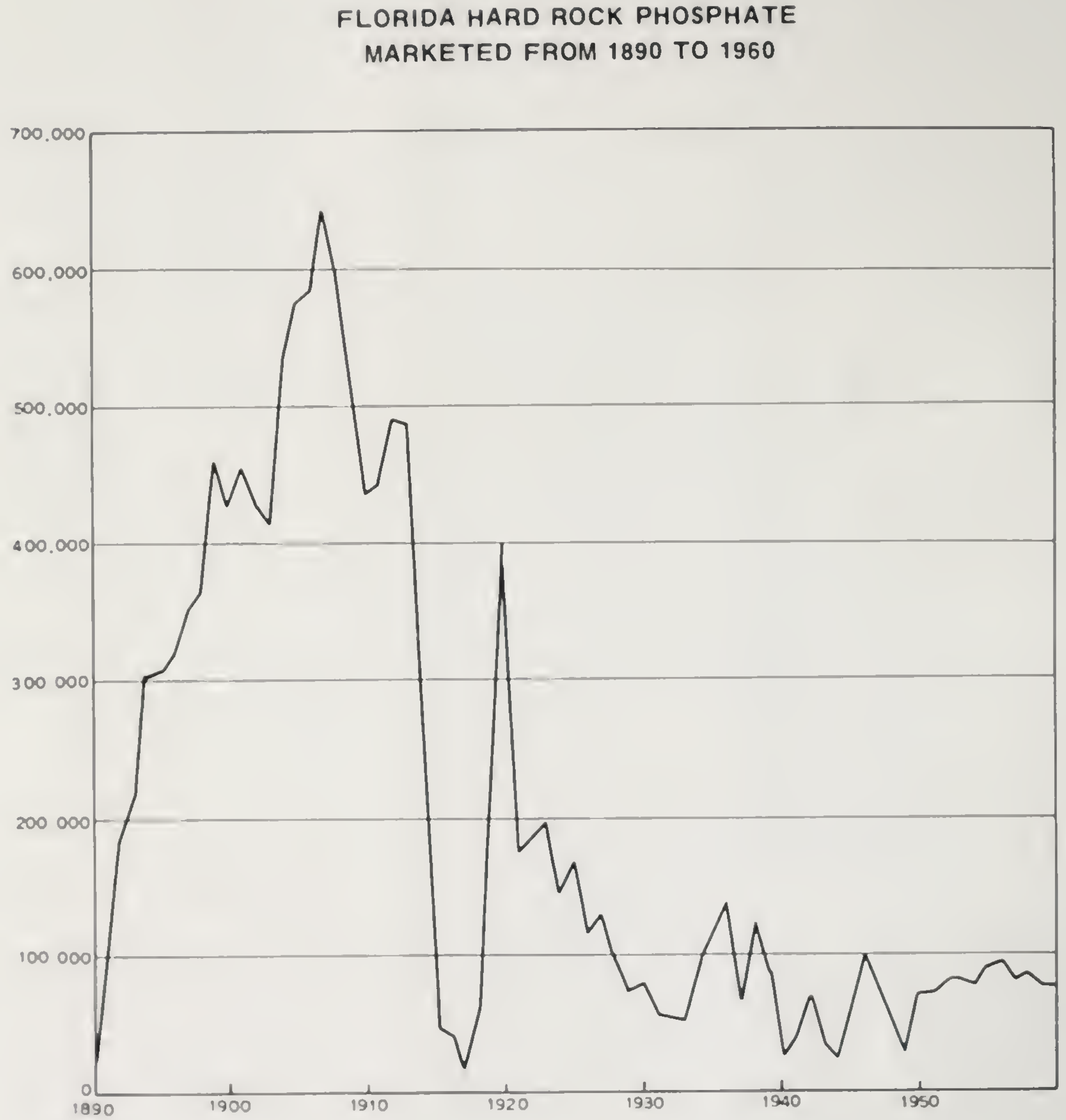
Phosphate rock is mined by open pits as are limestone and dolomite, but often the amount of overburden removed is much greater because of the comparatively higher value of phosphates. Early clearing off of overburden was done by horse or mule-drawn clamshell scoops, and the cleaned phosphate was mined with pick and shovel. Modern methods employ draglines for earth-moving and the ore is recovered by screening and flotation.

No hard-rock phosphate is mined today in Florida but the industry continues to produce, utilizing land-pebble deposits in south central Florida and certain soft-rock pits. The soft-rock phosphates are produced from slimes and waste materials that were abandoned by earlier hard-rock operations. Soft-rock mines are operating today in Citrus, Marion, and Gilchrist counties. The output is used for direct application to soils and for stock and poultry feed.

Reference to Figure 22 indicates the boom character of the phosphate industry, whose rapid rise coincided with Florida's railroad era between 1890 and 1900. The industry peaked to more than 600,000 long tons of production in 1909. Halted during World War I, the industry zoomed again in 1920, only to fall off rapidly throughout the decade which followed.

In summary, the extractive industries based on limerock and phosphate and their associated minerals have supported the local economies to an important extent. Phosphates first, in the 19th century, and then limerock during the rise of the automobile age in the 1920's, when extensive road-building began in Florida, and finally dolomite with improved agriculture after the Great Depression, provided local sources of nonfarm employment when none other was available.

Even today those industries play an important, although reduced, role in west central Florida. The value of production in 1969 and 1970, the last years for which complete data are available, is shown on Table 13. Sales totalled $9,520,000 in 1969, and $5,838,000 in 1970, with much of these amounts going into local payrolls.




Source: Espenshade and Spencer, USGS Bulletin 1118, 1963.

Figure 22 -- Florida Phosphate Production, 1890-1960.

Table 13 Value of Mineral Production in the Study Area Counties, 1969-70

| County | (thousands) 1969 | 1970 | Minerals Produced in 1970, in order of value |
|---|---|---|---|
| Alachua | 1299 | 1335 | Limestone |
| Citrus | 1673 | 1941 | Limestone, Clay, Phosphate |
| Dixie | None | None | |
| Gilchrist | W* | W* | Phosphate |
| Lafayette | None | None | |
| Levy | 1046 | W* | Limestone |
| Marion | 1761 | 2562 | Limestone, Fuller's Earth, Sand & Gravel Phosphate |
| Sumter | 3741 | W* | Limestone, Lime, Peat |
| Totals | $9520 | $5838 | |

*W - Withheld to avoid disclosing individual company confidential data

Source: Minerals Yearbook, 1970

The above has been accomplished at a cost of considerable degradation of the landscapes in the mining areas, where abandoned pits and piles of overburden occupy many acres. Some of these are reclaimable for recreational purposes, while others may be restorable for other uses, as is now being done in south central Florida.

NOTES TO CHAPTER VI

[1] William D. Reves, Mineral Resources Adjacent to the Proposed Trans-Florida Barge Canal, Florida State Geological Survey (Feb. 20, 1962).

[2] United States Department of the Interior, The Mineral Industry of Florida, reprint from the 1970 Bureau of Mine's Minerals Yearbook, p. 8.

[3] Ibid.

[4] Robert O. Vernon, Geology of Citrus and Levy Counties, Florida, Florida State Geological Survey Bulletin No. 33 (1951), p. 217.

[5] Ibid., p. 218.

[6] R. H. Hopkins, The Dolomitic Limestones of Florida, Florida State Geological Survey (Dec., 1942), p. 7.

[7] Vernon, The Geology of Citrus and Levy Counties, Florida, p. 223.

[8] United States Department of the Interior, The Mineral Industry of Florida, reprint from the 1970 Bureau of Mine's Minerals Yearbook, p. 7.

[9] James L. Calver, Mining and Mineral Resources of Florida, Florida State Geological Survey Bulletin No. 39 (1957), p. 50.

[10] Vernon, The Geology of Citrus and Levy Counties, Florida, p.195.

## CHAPTER VII

## LAND VALUES AND KARST

The marginal nature of the various agricultural operations carried on at present, under individual as contrasted with corporate ownership, in the Eocene outcrop area was referred to in Chapter I. Land use is primarily agricultural, and when land values are uninfluenced by other factors, such as proximity to job sources, the land values are near the low end of the scale for the entire state. Two karst features, however, which are present in the study area, can of themselves radically alter the value structure. These features are springs and lakes.

### Karst Springs

While appropriate note has been taken in the section under hazards of the negative aspect of springs as a karst feature, that aspect is very minor in terms of the total picture. A number of Florida's springs were analyzed in a recent joint effort by members of the U. S. and Florida Geological Surveys, which reached print in 1947. Certain of the springs of the study area were included in the state-wide coverage and furnish proper perspective for the consideration of this feature. According to the U. S. Geological Survey, the springs constitute one of the state's more important natural resources. As commercialized tourist attractions, they are the bases of business enterprises of considerable magnitude. The water supplies of several Florida municipalities are

piped from nearby spring pools. Sanitariums have been established at some. Private and public agencies have provided hotels, motor courts, cottages, dance pavilions, restaurants, boating, swimming, and fishing facilities. The rivers throughout a large part of Florida are beneficially affected by the comparatively uniform amounts of spring water they receive and their navigability is usually improved.[1]

The major springs are noted for their outstandingly large rates of discharge. The magnitude of these flows has created an interest and popularity which has attracted local resident, tourist, and scientist alike. The word "spring" is usually associated with a relatively small amount of water issuing from the ground and trickling into a nearby stream. In Florida, however, the larger springs issue from the ground in the form of rivers, some of which are large enough for commerical navigation. Either of Florida's two largest springs has sufficient water to supply a city of over 3,000,000 population, and any of one of 20 of the major springs would serve a city of over 500,000 population.[2]

Rainbow Springs in southwestern Marion County is in the study area, and is the second largest spring in the state. It is in the commercialized tourist category. A list of the better-known springs in the counties studied, and their measured rates of flow, follows. (Table 14). They are located on Map 13.

The flow of springs is measured either in second-feet, or millions of gallons per day (SF and MGD). Hydraulic engineers use second-feet to designate the flow of one cubic foot of water per second.

Table 14 Springs in the Study Area

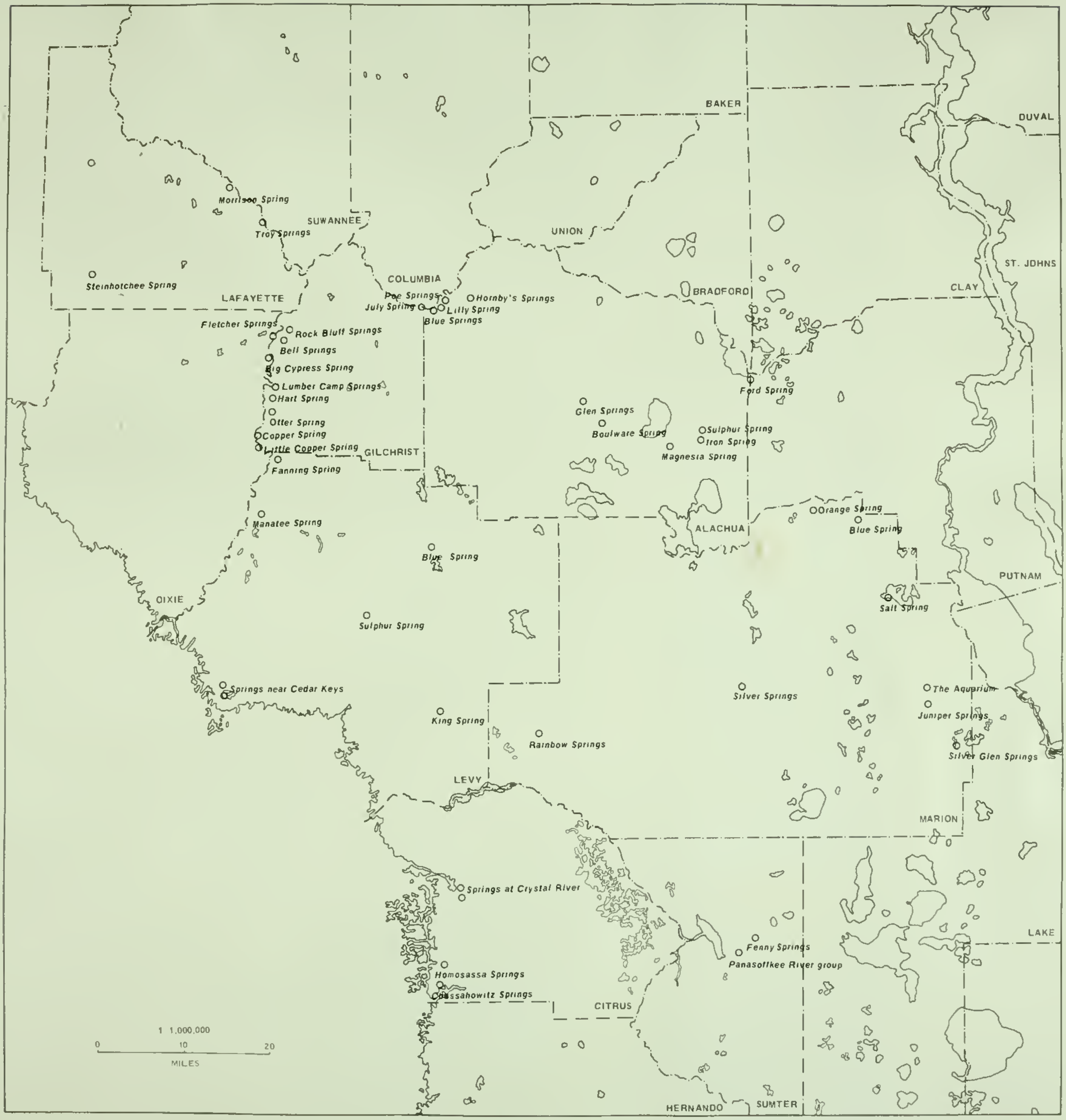
| County | Spring | Flow in Second-Feet | Flow MGD |
|---|---|---|---|
| Alachua | Glen Springs | .32 | .21 |
| | Magnesia Spring | .65 | .42 |
| | Poe Spring | 70.4 | 45 mgd |
| | Other: | | |
| | Blue Springs | | |
| | Boulware Spring | | |
| | Ford Spring | | |
| | Hornsby Springs | | |
| | Iron Spring | | |
| | July Spring | | |
| | Lilly Spring | | |
| | Sulphur Spring | | |
| | Two small springs near High Springs | | |
| Gilchrist | Hart Spring | 60.4 | 39 |
| | Lumber Camp Springs | 3.0 | 1.9 |
| | Otter Spring | 5.4 | 3.5 |
| | Rock Bluff Springs | 42.1 | 27 |
| | Other: | | |
| | Bell Spring | | |
| Layfayette | Morrison Spring | 51.6 | 33 |
| | Troy Springs | 102 | 66 |
| | Other: | | |
| | Steinhatchee Spring | | |
| Citrus Co. | Chassahowitzka Springs | 81.4 | 53 |
| | Homosassa Springs | 185 | 120 |
| | Hunter Spring | 62.9 | 41 |
| | Other: | | |
| | Cedar Hill Spring | | |
| | Other springs at head of Crystal River | | |

(continued)

Table 14 (Continued)

| County | Spring | Flow in Second-Feet | Flow MGD |
|---|---|---|---|
| Dixie | Big Cypress Spring | 12.4 | 8 |
| | Copper Spring | 18.8 | 12 |
| | Little Copper Spring | 2 | 1.3 |
| | Other: | | |
| | Fletcher Springs | | |
| Levy | Fanning Spring | 108 | 70 |
| | Manatee Spring | 168 | 109 |
| | Wekiva Springs | 72.9 | 47 |
| | Other: | | |
| | Blue Spring | | |
| | Several small springs near Cedar Keys | | |
| | King Spring | | |
| | Sulphur Spring | | |
| Marion | Blue Spring | 10.6 | 6.8 |
| | Juniper Spring | 12.8 | 8.3 |
| | Rainbow Spring | 699 | 452 |
| | Salt Springs | 81.1 | 52 |
| | Silver Glen Springs | 111 | 72 |
| | Silver Springs | 808 | 522 |
| Sumter | Fenney Springs | 21.6 | 14 |
| | Gum Slough Spring | 11.1 | 7.2 |
| | Panasoffkee River group | 22 | |
| | (formerly Branch Mill Spring group) | 22.5 | 15 |

# MAJOR SPRINGS




Map 13

A flow of one second-foot will fill an area of one acre to a depth of two feet in 24 hours. One second-foot also equals 0.646 millions of gallons per day, or 646,000 gallons. A first magnitude spring is defined as one with a probable average flow of 100 second-feet.[3] Of the 75 springs listed as being of first magnitude in the United States, Florida has the most of any single state, 17. While Rainbow Springs is the only first magnitude spring in the study area, there are a number of other major springs, in addition to the many minor and uncharted ones. Their principal effect is to stabilize the flows of the Suwannee and Santa Fe River basins, although they offer considerable local recreational use as well. The majority of the springs and their runs in the study area were visted by this student in the course of field work. Most remain in private ownership, with varying degrees of accessibility, and current usage varies from the highly developed commerical attraction at Rainbow Springs, to the smaller flows whose use is described as "stock-watering."

With the steep post-war rise in rural land prices, and the increased emphasis on outdoor recreation by all segments of the population, the market value of the springs and their surroundings have soared to astronomical heights. State agencies, only belatedly furnished with funds to make some of these areas available as state parks, have had to compete with astute private investors. Rainbow Springs as a developed commercial facility changed ownership in 1968 for a reported price of $1,000,000.* The total area available for development with the property

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* Personal communication, Keyes Realty, Miami, Florida.

is quite small so that it would not be suitable for public ownership and recreational use, in proportion to its market value today, four years later. The State Park System has, however, been taking steps in recent years to obtain the area of Blue Springs in the northwestern Alachua County portion of the study for a future State Park. Press releases in October of 1972 described the purchase by the State Department of Parks and Recreation of 275 acres at Blue Springs, including the land around the springs, and on the north side of Blue Springs Run, which feeds into the Santa Fe River a few hundred yards away.[4] An additional 325 acres south of the Run is desired by the state, which reportedly offered \$1,020,000 for the acreage. The present owners had earlier in 1972 paid \$781,000 for the acreage at a mortgage auction. The state's purchase price of the parcel around the springs and to the north has not been disclosed, but it could not have been less than that offered for the second parcel, so that at least \$2,000,000 is involved in the purchase of less than a section of land together with the spring itself. The Parks Department has announced that development for public use would be by private developers under license, a procedure which assures controlled development of facilities for public use without the commitment of additional state funds.

The Blue Springs area, when developed, will complement the existing State Park at Manatee Springs, near the Suwannee River in Levy County. Manatee Springs serves large numbers of people annually, with a majority of them probably being state residents. Both the Blue Springs and the Manatee Springs areas are still largely in their natural states, and

are exceptionally attractive. What has happened here is not a change in traditional land use, but a large-scale intensification of it, accompanied by increases in land values of several whole orders of magnitude. The state offer of $1,020,000 as reported for 325 acres must necessarily under state regulations reflect a professional appraisal of the value. The figure exceeds $3,000 per acre, for land ajoining the run but separated from the main springs and consisting mostly of woodland. Its value lies in its scenic attraction and the recreational amenities of the site, plus the capacity when developed to accommodate substantial numbers of people. Other springs and spring runs in the study area will naturally be affected in a comparable manner by the interest in the major springs.

Karst Lakes

It has been noted that lakes as various types of subsidence basins are a prominent feature of karst terranes, and this is the case in the study area. A classification of Florida lakes according to their shoreline characteristics was offered by E. W. Bishop in 1967.[5] The classification relates to geomophic and botanic features which are in most instances readily observable in the field, and which bear directly upon the suitability of the lakes for recreation, residential, wildlife, and other related uses. Bishop considers that the shorelines may be divided into eight identifiable classes, and that a given lake may have several of these classes representing the evolutionary stages of different parts of the shore. His tabulation of some of the characteristics of these eight classes is included here as Table 15.

Table 15 Some characteristics of the Shorelines of Florida Lakes

| Class Number | Name | Tree line at mean high water | Tree line lakeward of mean high water | Peat deposits present | Trees toppled lakeward | Dead cypress at edge of water | Dead upland trees at edge of water | Sand ridges lakeward of mean high water | Accessibility to open water | Swimming | Fishing | Wildlife |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sloping Swamp Forest | - | X | X | - | X | - | - | poor | poor | good | seasonally good |
| 2 | Consequent Shoreline | X | - | - | - | - | X | - | good | fair | good | fair |
| 3 | Wave Eroded Beach | X | - | - | X | - | X | X | good | good | good | good |
| 4 | Flat Swamp Forest | - | X | X | - | - | - | X | poor | poor | poor | occasionally good |
| 5 | Open Aquatic Forest | - | X | X | X | X | - | - | fair | fair | good | fair |
| 6 | Peat Marsh | X | - | X | - | - | - | - | poor | poor | good | excellent |
| 7 | Brush Shoreline | - | - | - | - | - | - | - | poor | poor | fair | fair |
| 8 | Altered Shore | - | - | - | - | - | - | - | gen. good | good-poor | poor | poor |

From Florida Lakes, Part 2, A Tentative Classification of Lake Shorelines, by E. W. Bishop, Division of Water Resources, Florida Board of Conservation, Tallahassee, Florida, 1967.

A total of 596 lakes is found in the eight counties, and lakes of all eight classifications have been visited by this student during the course of the field study. A small number of these lakes have been developed to a varying degree for use by residential communities, with the remainder being used for occasional recreation, the watering of stock and, infrequently, for irrigation.

Reference to Table 15 shows that when found in their natural states these lakes differ greatly in their suitability for the various uses which might be desired. Classes 2 and 3 are most suitable for water sports, swimming, fishing, and wildlife. A small number of lakes of these classifications are found in the Eocene outcrop area. Lakes of Class 6 are poor for boating and swimming, but offer good fishing and are excellent for wildlife. This class of lake is common in the Eocene outcrop area.

Concerning values, the lakes and ponds in agricultural use add only slightly if at all to the total value of farm property when such is on the market, and are assessed by county tax assessors at the same rate as the surrounding lands. If there is much marsh around the margins, the lakes and ponds may be assessed at even lower levels than the surrounding dry ground. In a karst area of southwestern Marion County in 1972, for example, with 100 percent evaluation as is now prescribed by Florida law, pine forest is assessed at $80, blackjack oak and scrub at $55, and lakes at $50 per acre.*

* Office of the Marion County Tax Assessor, Ocala, Florida.

For purposes of this study, a promotion called "Rainbow Lakes Estates" in southwestern Marion County was selected; it is an example of a karst lake property developed as a large retirement and residential community. This development combines a number of features which have an impact upon the economics and demography of the study area, and certain implications for the future.[6] (Also see Map 14 which shows location of Rainbow Lakes Estates and fluctuations in lake shoreline between 1940 and 1964).

Before development began in 1959, the area was and still is, in large part, indistinguishable from many other subregions of the Eocene outcrop. There is a rolling to slightly hilly landscape on sandy soils with a growth of turkey oak, blackjack oak, various pines, and scrub plants. Such lands have historically been used for cattle grazing, or infrequent lumbering. When used as cattle ranches, the holdings tend to be large, with many of them running to thousands of acres in the hands of single ownerships. Except for fencing and occasional improved pastures, and minus the loss of the best trees to early logging operations, the lands remain undeveloped and unchanged, much as they were a century ago. The population which lives off the land was and is sparse. In short, the picture here as elsewhere in the rural parts of the study area was that of agriculture barely holding its own, or in obvious decline.

In addition to the sparse population, the low tax base of the area demonstrates the marginal character of agriculture as full-time pursuit. Samplings of land values picked at random from the Marion County Tax

Assessor's office show that in the mid-1950's, unimproved land in the general area of Rainbow Lakes Estates bore assessments as follows:

| | |
|---|---|
| * $22.50 per acre | Pasture |
| $21.00 per acre | Woodland |
| $30.00-$60.00 per acre | Lakes, limerock pits, sinkholes, marshes and ponds. This is a general category and includes springs as well. |

The value for wet lands and rockpits seems high in comparison with the other categories, but it should be recalled that commercial rockpits have been big business in Marion County for many years and whether operated directly by their owners, or whether worked on a royalty basis, the most common method, they were understood to be profitable. The assessed values which at first glance seem high, were probably an important tax concession to the rock industry of the time.

The fair market value of undeveloped lands in the general area selected to become Rainbow Lakes Estates is seen to span from $21.00 to $60.00 per acre at about the time of purchase. A prime factor influencing the selection of the acreage was the presence of two lakes, Lake Bonable and Little Lake Bonable, in the southwest corner of what ultimately was a 13,000-acre development. Lake Bonable's surface is at 63' above mean sea level and covers 211 acres. It lies between low sand hills and has an irregular shoreline which fluctuated and meandered

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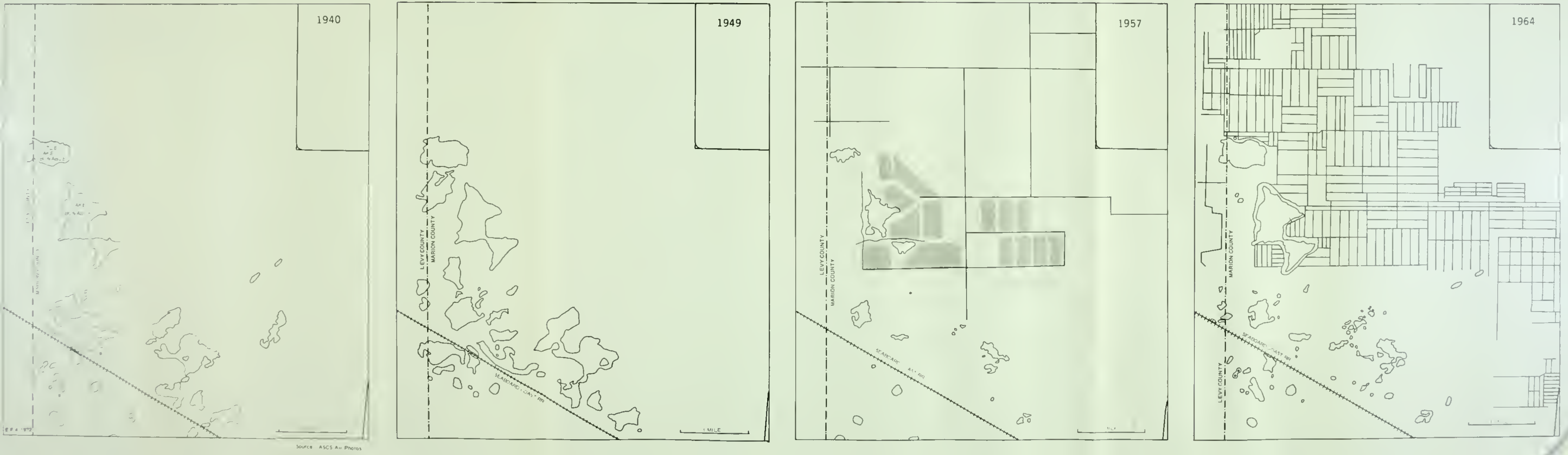
* These are corrected figures. The actual assessments were only one-third the amounts shown, but valuation was only a fraction, some 30-40 percent of the market value. For report purposes, then, values were rounded out at triple the tax assessor's figures to suggest fair market value.


# RAINBOW LAKES ESTATES

LAKE AREA FLUCTUATION BETWEEN 1940–1964
AND
THE DEVELOPING PLAT OF THE RAINBOW LAKES ESTATES COMMUNITY



significantly in earlier years. A series of four aerial photos taken between 1940 and 1964 highlights the fluctuations. A quarter mile northwest of Lake Bonable lies Little Lake Bonable, at 55' above mean sea level, and averaging 157 acres of surface. Both lakes have consequent shorelines, Class 2 in Table 15, indicating a youthful lake of relatively recent origin. Lake Bonable has streams flowing both in and out of it, while Little Lake Bonable, which is lower than Lake Bonable, is stream-fed with no outlet.

Pegging their appeal on the presence of these rather insignificant lakes, the promoters designed a road grid with the lakes as their focus and began a strenuous national advertising campaign which included visual and radio material. The name of the venture itself seems to this student to borrow from the already successful Rainbow Springs commercial promotion nearby, and the advantage of the Florida image. Most Floridians of the writer's acquaintance consider Marion County's location to be too far north for winter resort purposes, but as land prices increased in the warmer parts of Florida, promotion moved northward, and the Rainbow Springs operation is an example of this trend.

The recreational potential of the lakes was emphasized in the advertising, and a nautical theme, however incongruous for bucolic inland Florida, was marketed. The street names bear out the watery format, and in addition to aquatic names for those roads with a view of the lakes, streets located miles away in the scrub bore the names of pelagic marine fish, such as sailfish, kingfish, and,bonita. There are no streets named after the Florida fish native to the lakes themselves,

Table 16 Water-Related Names for Streets

| | |
|---|---|
| Rainbow Lakes Boulevard | Lakeland Heights Avenue |
| Deep Water Court | Nautilus Drive |
| Beach Boulevard | Barnacle Drive |
| Soundview Drive | North Lake Boulevard |
| Shorewood Drive | Sea Cliff Avenue |
| Freshwater Court | Wave Lane |
| Tiger Lake Boulevard | Admiral Landing Drive |
| South Beach Court | Harbor Hills Road |
| South Lakes Court | Timberlake Road |
| South Haven Court | Edgewater Boulevard |
| South Water Court | Anchor Boulevard |
| Tiger Lake Park | Bluegill Avenue |
| Clearwater Court | Tarpon Avenue |
| Driftwood Court | Sailfish Avenue |
| Waterview Court | Kingfish Avenue |
| Marine Boulevard | Bonita Avenue |
| North Beach Boulevard | |

i.e., there are no Bream, Catfish, Crappie, or Mudfish streets. (See Figure 23). A partial list of the actual names follows as Table 16.

Lots were set at one-fourth acre and one acre in size, and eventually some 17,000 were platted throughtout the almost 20 square miles of land. Sales were brisk.

There was some alteration of the shorelines, and recreational areas, boat ramps, and a sand beach were built. (See Figure 24). Access to the lake is jointly available to the adjoining lot owners, as well as to the rest of the lot buyers.

Three clubhouses, one of which is for youth, were built for the community, and there are also (1972) a volunteer fire station, a weekly newspaper listing social events, a small medical center with ambulance service, and several service stores.

Building restrictions as filed by the developers call for houses to have a minimum of 600 square feet of living area, with carports in addition. This is on the small side for Florida. Just over 500 houses have been built as of 1972, and these are found in irregular clusters, with large expanses of vacant lands separating them. Miles of asphalt roads were built on a grid system, and many of the roads follow the topography in a curving, pleasing manner consistent with good esthetic practice.

Sale prices were from $1,595 to $2,000 for the quarter-acre lots, and from $2,695 to $4,000 for the more remote acre-sized lots. Prices were higher for the lots fronting on the lakes themselves. These were platted in 35-foot widths, with depths varying from 150' to 300'

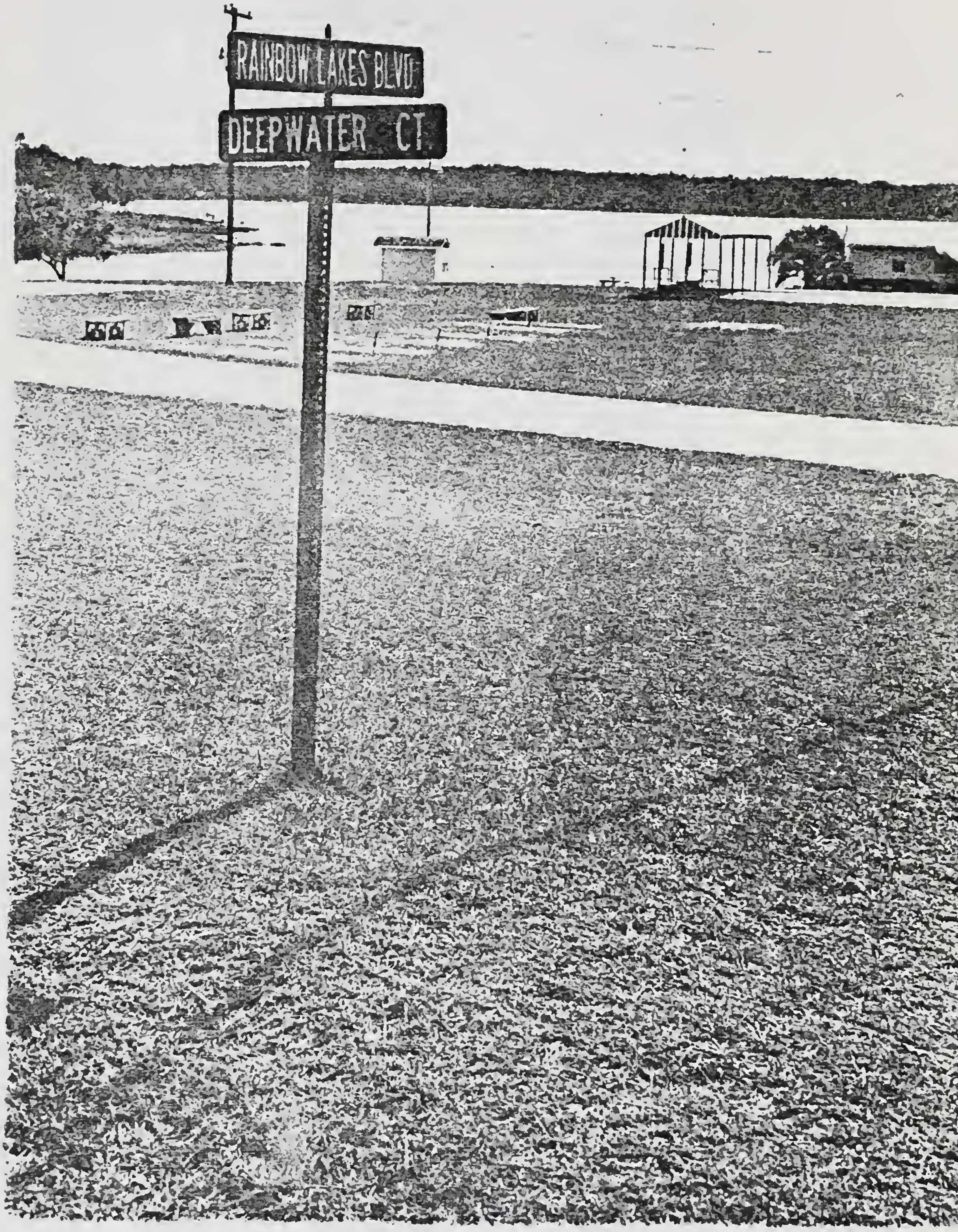



Figure 23 -- Signpost Indicates Water-Oriented Names for Streets in Rainbow Lakes Estates

Figure 24 -- Rainbow Lakes Estates Beach and Recreation Area.

depending upon the contours of the sand hills abutting the water. A minimum of two lots was required to form a lakefront residential site, so that 70' is the most common width. Certain buyers added a third lot to make for 105' of site width. The typical 70' waterfront homesite sells for $3,200 to $4,500 in 1972, with the price differential depending more upon the personal circumstances of buyer and seller than upon physical factors.*

The waterfront lots (combined to form acre-sized increments for purposes of this study) command a price of from $8,960 to $12,800 per acre. They demonstrate amply that market support at the elevated figure will be given a karst lake feature following relatively modest development of the hinterland, along with sales promotion scaled to the size of the development. These data are presented in Table 17 following for ready comparison.

From Table 17 it is seen that acreages originally valued at $21.00 to $60.00 per acre prior to development were re-sold, after limited development, for prices of from $2,695 to $12,800 per acre, with the presence of lakes as probably the single major factor making the subsequent properties marketable at these prices.

That the Rainbow Lakes case is not an isolated one, is supported by related research done by this student during the study period. The other field inquiry was performed as part of the qualifying examination for admission to candidacy for the doctoral degree, in May, 1971, and fulfilled a requirement to prove or disprove the hypothesis that sinks

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* Joe L. Cobb Realty, Inc., Dunnellon, Florida.

Table 17 Market Data on Rainbow Lakes Acreage

| Type of Property | Value Per Acre | Value Per Square Foot |
|---|---|---|
| Pre-development pasture, woodland, lakes, marshes, and ponds. | $21.00 to $60.00 | $.0004 - $.0013 * |
| Post-development one-acre residential lots in 1972 | $2,695.00 to $4,000.00 | $.06 - $.09 ** |
| Post-development 1/4 acre residential lots in 1972 | $6,380.00 to $8,000.00 | $.15 - $.18 ** |
| Post-development waterfront residential lots in 1972 | $8,960.00 to $12,800.00 | $.21 - $.29 *** |

Source: * Office of Marion County Tax Assessor, Ocala, Florida.
** Rainbow Lakes Estates Development and Realty Corporation, Rainbow Lakes Estates, Florida.
*** Joe L. Cobb Realty, Dunnellon, Florida.

or depressions filled with water in a part of Florida which adjoins the karst limestone plain "provide a clear-cut enhancement of land values for the owners of land adjacent to such depressions."

For the research, the market data approach was used in order to systematize actual costs in the comparison of similar properties. As in the Rainbow Lakes evaluation, only current sales of land without structures were used. Waterfront lots in small developments were found to command price multiples of 7 to 1 over landlocked lots. These provided facilities only to the extent of primitive sand roads and street signs, and the attraction of lake access for the owners of landlocked lots. The price structure is shown in tabular form. (See Table 18).

Further analysis of the cost data, and comparison between individual lakes of differing appeal in the Melrose study area brings out the following observations:

> Swan, Serena, and Halfmoon Lakes are similar in waterfront prices; yet it is evident to an observer that the lakes are not equally attractive. Swan Lake is the only one large enough for waves. They all fluctuate from four to five feet in elevation. Even the relatively low price for the landlocked lots has lead to widespread subdividing, but very few sites are occupied--and those mostly by trailers. The contrast in values between subdivided and unsubdivided acreage is even more pronounced than contrasts inside the developments. Scrub acreage is assessed at $75.00 per acre compared with scrub lots which total $871.20 per acre, and high land which borders on some of the lakes could be worth $6,098.40 per acre instead of the $300.00 which is their current assessment. This is a factor of 20 to 1. The evidence as to the drawing power of water-oriented recreation sites is clearcut.

It appears to this writer that many of the above considerations are generally applicable to karst lake environments in west central Florida.

Table 18 Summary of Costs for Lake-oriented Lots in Melrose, Florida

| | | Cost Per Square Foot |
|---|---|---|
| Waterfront Lots | Average | $.14 |
| Landlocked Lots | Average | .02 |
| | | **Total Cost** |
| Waterfront Lots | Average | $3,494.00 |
| Landlocked Lots | Average | 375.00 |

Source: E. F. Abbott, Research Exercise.

Aside from the factor of land values, an important change in land use is involved here, with concomitant social, economic, and demographic problems. Geographers treat of people on the land, hence certain comments are in order here. In the case of Rainbow Lakes Estates, an overwhelming majority of the residents are from other states. Their homes are largely isolated, and the former pastures and scrubby woodlands dominate the landscape. Opinions among residents are mixed as to whether the settings should be considered pleasant or on the bleak side, or whether or not the present land use is an improvement over its former state.

In the judgment of this writer, most of the present residents have probably improved their physical situations, because the quality of life in the industrially blighted areas of the northeastern United States from which most of them have migrated leaves much to be desired. The recreational possibilities of the combined area of the lakes, 368 acres, seems adequate for the use of the present population, and there is much to be said for the escape from the crowding which is so typical of urban acreas. On the other hand, if the 17,000 homesites were to be built upon at an average of 2.5 residents per household, a population of 42,500 would result. Marion County's total population in 1970 was 69,030. It seems clear that any significant increase in the population of the remote development would increase the demand for services from the county, and will require planning on an order not heretofore seen in that county.

## NOTES TO CHAPTER VII

[1] G. E. Ferguson _et al_., _Springs of Florida_, Florida State Geological Survey Bulletin No. 31 (1947), p. 9.

[2] _Ibid_., p. 37.

[3] _Ibid_., p. 29.

[4] _The Orlando Sentinel_ (November 1, 1972).

[5] E. W. Bishop, _A Tentative Classification of Lake Shorelines, Florida Lakes_, Florida State Division of Water Resources (1967), p. 56.

[6] E. F. Abbott, _Research Exercise_ (University of Florida Geography Department, May 14, 1971), p. 29.

# CHAPTER VIII

# CONCLUSIONS

The major objective of this study has been to gain an understanding of the effect of solution landforms on land use in west central Florida. When the facts developed by this inquiry are reviewed and placed in historical perspective, with man as an agent of geographic change, one feature emerges and predominates. The chief influence of karst on land use has been a limiting one.

Since the beginning of American settlement in this region of Florida, the limitation factor has applied. While the woodlands and prairies overlying the karst strata were left untouched, the richer hammock lands to the east were first sought after, even at the cost of bloodshed with the Seminole owners. The limestone plains were distinctly second choice, in recognition of their limited desirability. When settlement did begin, it was sparse, and small-scale subsistence homesteads were the rule. The prevalence of these small economic units set limits on both the productive base of the region, and on the small trading centers which arose to support the farmers and stockmen.

The limitations on crop yield have continued into the modern era of scientific farming, with its improved plantstuffs, soil nutrients, and machinery. Yet today's full-time farmers in the region,

although consolidating into fewer, larger, and more efficient operations, still have regularly lower yields than in the more favored regions of Florida and the coastal plain.

Karst features to an important extent are a hazard in the study area. The hazards extend to pocketbook, livestock and person. They warrant inclusion of karst features, such as sinkholes, on a geographer's list of natural hazardousness of place.

There are two levels of hazard perception in the study area, a lower level, and an elevated level. The users of the land tolerate the hazards, or accommodate to them, as simply an additional factor to add to the complex of problems and uncertainties with which most growers must cope. Most users depreciated the value of their own time spent in reacting to karst problems, and accepted losses caused by karst features if these stayed within what were felt to be acceptable limits. Thus, it is concluded that growers in the study area function despite the presence of karst features, rather than because of them in any discernible sense.

Persons involved professionally in the earth sciences perceive the hazards in larger dimensions, and are moved to larger-scale solutions and more of a spirit of urgency. A potential exists for large-scale future damage in the vector of water pollution. The potential danger applies to individual farmers widespread throughout the region, and to the inhabitants of the population centers. The current practices of discharging sewage effluent from the popu-

lation centers into karst features such as lakes and sinkholes, from which access can be had into the aquifers of the region, are recognized as a peculiarly karst-associated threat.

Sinkholes and other subsidence events are a continuing maintenance drain on the State Department of Transportation, and are a drain not regularly met with by road maintenance organizations not on karst terranes.

The occurrence of subsidence events in the region are the object of research designed to seek methods of minimizing both the hazards and problems. Combinations of established techniques, such as stereo-pair interpretation, and newer, such as differential selective photography, are used as part of the research effort. It is concluded that an optimum over-all technique has yet to be found.

Karst features have at times been beneficial to the region. Limerock and dolomite as karst-related resources along with phosphate, have played ancillary roles in the economy of the study area, providing non-farm wage employment to parts of the labor force, off and on, over a number of decades. Their importance was reinforced by the fact that other sources of wage employment were generally not available in the region during those times of mineral extraction. Hence, the karst resources when they could be marketed compensated in part for the limitations on the agricultural potential of the region. While the population figures for the study region have remained low, it may be concluded that population decline was arrested by the use

of karst resources when these were in demand.

The increased development of major karst springs for state parks is an intensification of early and traditional land use here. Since the earliest settlement, these springs have been favored as fishing, boating, and gathering places.

The competition between state and commercial buyer, and the increased participation in leisure pursuits by all segments of the population, have been responsible for marked price rises in such spring properties. The process of making the natural amenities of the springs available to more of the people, despite the price competition, is a measure of intensified, rather than changed, land use.

The creation of new residential communities, using karst features such as lakes as their center of attraction and even as their entire raison d'etre, marks an entirely new type of land use in the study area. There are many such lakes, as has been shown, and the creation of new communities, as is a current trend in the state, involves marked change in the demography of the region, while providing major challenges in overall land use planning.

Land use in the study region heretofore has shown frequent short-term changes, but overall use patterns suggest that on a regional basis, agricultural areas have remained fairly definite in location. The patterns generally correspond to those of the natural vegetation; the hammock lands most often yield to crops, wet prairie land is little changed, pine land depending on economic conditions has often

been farmed. The overall proportions between forest, pasture, and cropland remain about the same.

In summary, the study shows that karst influence has limited the area's productivity in comparison with other areas, and has limited the full use of the land for whatever purpose was elected, whether for forestry, stock-rearing, or field crop. Population growth likewise has been limited over the decades. Karst features have been marginally useful as mineral resources, but these are now relatively unimportant. The use of major springs for their recreational amenities has become reinforced. We also observe an entirely new land use, the creation of entire new communities based on a karst feature, and as has happened so often before, the emergence of new challenges.

APPENDIX I

STATISTICAL ANALYSIS OF KARST FEATURE DATA

BY J. T. McCLAVE AND R. L. OTT

It was desired to estimate the number of karst features/acre of land falling into one of twenty categories:

| Land Use | Soil Type |
|---|---|
| 1. Cropland | 1. 3 |
| 2. Forest | 2. 5-8 |
| 3. Pasture | 3. 4-9 |
| 4. Idle | 4. 12 |
| | 5.. Other |

We first defined

$m_{ij}$ = # karst features in land use - soil type combination. (ij), $i = 1, \ldots, 4$, $j = 1, \ldots, 5$.

and

$n_{ij}$ = # map points falling in the same (ij) cell.

Since each point represents 4.4 acres, an estimate of the total sampled land in the (ij) category is $(4.4)n_{ij}$.

We had 55 photographs of the area of interest each covering 160 acres. Defining

$\rho_{ij}$ = true # karst/acre of land in category (ij)

we wanted to estimate $\rho_{ij}$ using the photo data. Since

APPENDIX I (continued)

$$\rho_{ij} = \frac{m_{ij}}{(4.4)n_{ij}} ,$$

we can use the usual ratio estimator

$$\hat{\rho}_{ij} = \frac{\sum_{k=1}^{\delta_{ij}} m_{ijk}}{4.4 \sum_{k=1}^{\delta_{ij}} n_{ijk}}$$

where

$m_{ijk}$ = # karst features in (ij) cell on photo k

$n_{ijk}$ = # map points in (ij) cell on photo k

and

$\delta_{ij}$ = # photos on which $n_{ijk} > 0$.

The need to introduce $\delta_{ij}$ is obvious when one realizes that no estimate of $\rho_{ij}$ can be made from a photo on which $n_{ijk} = 0$.

We first calculated $\hat{\rho}_{ij}$ for all (ij) combinations and intended to see whether the data indicated differences in the $\rho_{ij}$'s. However, the $\delta_{ij}$'s were so small in many cases that statistical comparisons were greatly hampered by lack of data. The table following gives $\hat{\rho}_{ij}$ and $\delta_{ij}$ for all cells:

APPENDIX I (continued)

Table 1.

$\rho_{ij}$ and $\delta_{ij}$

| | Cropland | Forest | Pasture | Idle |
|---|---|---|---|---|
| 3 | .003 | .011 | .000 | .031 |
| | 9 | 15 | 5 | 4 |
| 5-8 | .032 | .121 | .234 | .019 |
| | 10 | 15 | 9 | 6 |
| 4-9 | .058 | .130 | .127 | .074 |
| | 30 | 26 | 18 | 13 |
| 12 | .000 | .097 | .088 | - |
| | 3 | 12 | 4 | 0 |
| Other | .091 | .155 | .026 | .038 |
| | 8 | 12 | 10 | 6 |

The reader will notice the small $\delta_{ij}$'s and understand the reluctance to place any faith in inferences about $\rho_{ij}$ differences.

In order to overcome the small samples, we decided to first compare all land use categories disregarding soil types, and, then to compare soil types disregarding land use. Thus we computed

$$\rho_i = \frac{\sum_{j=1}^{5} \sum_{k=1}^{\delta_{ij}} m_{ijk}}{4.4 \sum_{j=1}^{5} \sum_{k=1}^{\delta_{ij}} n_{ijk}}$$

to estimate

APPENDIX I (continued)

$$\rho_i = \frac{\sum_{j=1}^{5} m_{ij}}{4.4 \sum_{j=1}^{5} n_{ij}}$$

the true number of karst features/acre of land use i. These estimates are given below.

Table 2.

$\hat{\rho}_i$

| Cropland | Forest | Pasture | Idle |
|---|---|---|---|
| .048 | .366 | .089 | .047 |

An estimated variance-covariance matrix was calculated so we could obtain

$$Z = \frac{\rho_i - \rho_{i'}}{S_{i,i'}}$$

where $S_{i,i'}$ is an estimate of the standard deviation of the difference between $\hat{\rho}_i$ and $\hat{\rho}_{i'}$, obtained by the square root of addition of the two estimated variances minus twice the estimated covariance.

The Z values are given below:

Table 3.

Z Values for Land Use Comparisons

| | Z | | Z | | Z |
|---|---|---|---|---|---|
| C-F | -1.53 | F-P | 1.31 | P-I | 1.08 |
| C-P | -2.08 | F-I | 1.48 | | |
| C-I | 0.19 | | | | |

APPENDIX I (continued)

This leads to the inference that $\rho_{cropland}$ and $\rho_{idle}$ are less than $\rho_{forest}$ and $\rho_{pasture}$. The significance level for such a conclusion would be about .10.

This was now repeated for soil types, calculating

$$\rho_j = \frac{\sum_{i=1}^{4} \sum_{k=1}^{\delta_{ij}} m_{ijk}}{4.4 \sum_{i=1}^{4} \sum_{k=1}^{\delta_{ij}} n_{ijk}}$$

The results are summarized below:

Table 4.

$\rho_j$

| 3 | 4-9 | 5-8 | 12 | Other |
|---|---|---|---|---|
| .009 | .133 | .088 | .097 | .106 |

The Z values are calculated as before:

Table 5.
Z Values for Soil Type Comparisons

| | Z | | Z | | Z |
|---|---|---|---|---|---|
| 3 : 4-9 | -2.10 | 4-9 : 5-8 | 0.61 | 5-8 : 12 | -0.11 |
| 3 : 5-8 | -1.98 | 4-9 : 12 | 0.33 | 5-8 : Other | -0.36 |
| 3 : 12 | -1.81 | 4-9 : Other | 0.36 | 12 : Other | -0.20 |
| 3 : Other | -4.14 | | | | |

The clear inference here is that $\rho_{type\ 3}$ is less than the others, which do not appear to be significantly different. Again the significance level is about .10.

# APPENDIX II

## QUESTIONNAIRE FOR FARMERS

Name and address of farm operator ____________________

____________________

Size of farm as estimated __________

Percent of land taken up by sinks and outcrops __________

Percent of land in crops, estimated __________

Percent of land in pasture, estimated __________

Percent of land in forest, estimated __________

100%

1. How large is your farm? __________

2. Do you rent land? How Much? __________

3. How much land do you have in crops? __________

   permanent pasture? __________

   forest? __________

4. Please locate and describe sinkholes or rocky outcrops on your land. ____________________

5. What is your estimate of the amount of land they "use"?

   ____________________

6. How have they affected the size of your fields?

   ____________________

7. How have they affected the shape and the fencing of the fields?

   ____________________

8. Is your decision to use land for cropland, or grazing land, or forest land influenced by the sinks and rocky areas?

   ____________________

APPENDIX II (continued)

9. Do you use mechanized equipment, and how is its use affected by slope and roughness?

______________________________

10. What have sink holes cost you in money and time?
(Have you lost animals?)
(Have you filled any and reclaimed the land?)

______________________________

## BIBLIOGRAPHY


Abbott, E. F. Research Exercise. University of Florida, Geography Department, May 14, 1971.

Abbott, Elizabeth F. "Twenty Springs of the Oklawaha." Gainesville: Florida Defenders of the Environment, 1971.

Agricultural Stabilization and Conservation Service. Agricultural Conservation Program Proposal, June, 1969.

Agricultural Stabilization and Conservation Service Regional Office, Gainesville, Florida, Press Release, January, 1971.

Bigelow, Gordon E. "History of Man in the Oklawaha Valley." Environmental Impact of the Cross-Florida Barge Canal. Gainesville: Florida Defenders of the Environment, 1971.

Bishop, E. W. A Tentative Classification of Lake Shorelines, Florida Lakes. Florida State Division of Water Resources, 1967.

Brooks, H. K. Rate of Solution of Limestone in the Karst Terrane of Florida. Florida Water Resources Research Center Publication No. 6, 1967.

Burton, Ian and Kates, Robert W. "The Perception of Natural Hazards in Resource Management." Reprinted from Natural Resources Journal, Vol. 3, No. 3, January, 1964.

Calver, James L. Mining and Mineral Resources of Florida. Florida State Geological Survey Bulletin No. 39, 1957.

Cash, W. T. The Story of Florida. New York: American Historical Society, 1938.

Cason, James H. "Lake Alice - A Study of Potential Pollution of the Floridan Aquifer." The Compass of Sigma Gamma Epsilon, Vol. 47, No. 4, May, 1970.

Center for Water Resources Research. "Comments on Lake Kanapaha Sewage Treatment Environmental Assessment Statement," May, 1972.

Coker, A. E., Marshall, R., and Thompson, N. S. "Application of Computer Processed Multispectral Data to the Discrimination of Land Collapse (Sinkhole) Prone Areas in Florida," Presented at the NASA Second Annual Earth Resources Aircraft Program Status Review, 1969.

Corbel, J. Notes sur les Karsts Tropicaux. Revue de Géographie de Lyon XXX, 1 Lyon, 1955. Cited by H. Lehmann in Report of the International Geographical Union Commission on Karst Phenomena, 1956.

Cotton, C. A. "Limestone Landscapes," Landscape. Cambridge: University Press, 1941.

Davis, John H. General Map of Natural Vegetation of Florida. University of Florida Agricultural Experiment Station, 1967.

Dicken, S. N., and Brown, Jr., H.B. "Soil Erosion in the Karst Lands of Kentucky." Washington, D. C.: United States Department of Agriculture Circular No. 490, 1938.

Dolliver, Claire Vincent. "The Geomorphology of the West-Central Florida Peninsula." University of Florida Thesis, 1965.

Environmental Engineering, Inc. "Report on Building Foundations Suitability." Gainesville, September 4, 1972.

Fenneman, N. M. Physiography of the Eastern United States. New York: McGraw-Hill Book Co., 1928.

Ferguson, G. E., Lingham, C. W., Love, S. K., and Vernon, R. O. Springs of Florida. Florida State Geological Survey Bulletin No. 31, 1947.

Florida Agricultural Experiment Station. General Soil Map of Florida. Soil Conservation Service, 1962.

Florida Agricultural Experiment Station. Principal Soil Areas of Florida, A Supplement to the General Soil Map. University of Florida, 1967.

Florida Agricultural Experiment Station, Soil Survey, Alachua County, Florida. University of Florida, 1954.

Florida Handbook. Tallahassee: The Peninsular Publishing Co., 1971.

Florida Legislature. Senate. Bill #1106. Hearing Relative to Implementation. Transcribed in full, June 2, 1969.

Florida State Treasurer's Office. Bulletin No. 453, Implementation of SB-1106, June 16, 1969.

Florida Times-Union (The). June 9, 1970.

Gainesville Sun (The). January 23, 1972, February 22, 1972, March 6, 1972, March 10, 1972, September 13, 1972, September 17, 1972.

Garrigus, W. M. "Roughness of Terrain as a Factor in the Areal Variation of Agricultural Productivity in Ohio," Paper presented at the Annual Meeting of the Association of American Geographers, Columbus, Ohio, 1965.

Girard, Jr., Oswald, W. "The Geology of the Gainesville West Quadrangle, Alachua County, Florida." University of Florida Thesis, 1968.

Goodman, James A. Physiography and Agricultural Land Use in a Portion of the Pennyroyal Region in Warren and Edmonson Counties, Kentucky, Northwestern University Dissertation, 1963.

Griffis, S. H. "Correlation Between the Remote Sensing Method Aerial Photography and Stereo-Pair Method of Aerial Photography," Florida State Department of Transportation, Geology Section, April, 1970.

Hewitt, Kenneth, and Burton, Ian. The Hazardousness of a Place. Toronto: University of Toronto Press, 1971.

Hopkins, R. H. The Dolomitic Limestones of Florida. Florida State Geological Survey, December, 1942.

Jillson, W. R. "Land of Ten Thousand Sinks." Sketches in Geology. Louisville: C. T. Dearing Printing Co., 1928. Reprinted from Transactions, Kentucky Academy of Science, Vol. I, pp. 143-144, 1924.

Jones, Wellington D. "A Method of Determining the Degree of Coincidence in Distribution of Agricultural Uses of Land With Slope-Soil-Drainage Complexes." Reprinted from Transactions, Illinois State Academy of Science, Vol. XXII, 1930.

Kaye, Clifford A. "The Effect of Solvent Motion on Limestone Solution." Journal of Geology, Vol. 65, No. 1, January, 1957.

Lamarck, J. B. Hydrogeology. Urbana: University of Illinois Press 1964. First published in 1802 at the author's expense.

La Valle, Placido. "Some Aspects of Linear Karst Development in South Central Kentucky." Annals of the Association of American Geographers, Vol. 57, No. 1, 1967.

Lehmann, H. Introduction, Second Rapport of the Commission on Karst Phenomena. XIX International Geographical Congress, Norden, July-August, 1960.

Levy County Agricultural Stabilization and Conservation Service. Pamphlet, Pollution in Levy County, 1970.

Lipchinsky, Zelek Lawrence. "A Study of the Origin of Limestone Caverns in Florida." University of Florida Thesis, 1963.

Lyle, C. V., and Toon, T. G. "Normalized Crop and Pasture Yield Estimate (Current 1960, and Projected, 1975 and 2000)." Southeast River Basin's Study Area, U. S. Study Commission, United States Department of Agriculture, March 1961.

Marschner, Francis Joseph, and Reuss, Lawrence Adkins. Inventory of Major Land Uses in the United States. Washington: United States Government Printing Office, 1948.

Meinzer, O. E. Ground Water. Physics of the Earth IX. New York: McGraw-Hill Book Co., Inc., 1949.

Meyerhoff, Howard A. "The Texture of Karst Topography in Cuba and Puerto Rico." Journal of Geomorphology 1-2, 1938-9.

Monroe, Watson. A Glossary of Karst Terminology. United States Geological Survey Water Supply Paper 1899-K, 1970.

Monroe, Watson H. "The Karst Features of Northern Puerto Rico." National Speleological Society Bulletin, Vol. 30, No. 3, 1968.

Moore, Gerald K., Burchett, Charles R., and Bingham, Roy H. Limestone Hydrology in the Upper Stones River Basin, Central Tennessee. State of Tennessee Department of Conservation, Division of Water Resources, 1969.

National Observer (The). September 16, 1972.

Orlando Sentinel (The). November 1, 1972

Puri, Harbans S., Yon, Jr., J. William, and Woodson, R. Oglesby. Geology of Dixie and Gilchrist Counties, Florida. Florida State Geological Survey Bulletin No. 49, Tallahassee, 1967.

Pyle, E. T. Home Country. New York: William Sloane Associates, Inc., 1947.

Reves, William D. Mineral Resources Adjacent to the Proposed Trans-Florida Barge Canal. Florida State Geological Survey, February 20, 1962.

Sanders, E.M. "The Cycle of Erosion in a Karst Region (after Cvijić)." The Geographical Review, 1921.

Sauer, Carl Ortwin. Geography of the Pennyroyal. Frankfort: The Kentucky Geological Survey, 1927.

Sellards, E. H. Underground Water Supply of Central Florida. Florida State Geological Survey, 1908.

Sellards, E. H., Harper, Roland M., Mooney, Charles N., Latimer, W. J., Gunter, Herman, and Gunter, Emil. "Natural Resources Survey of an Area in Central Florida." Seventh Annual Report, Florida State Geological Survey, 1915.

Shimer, John A. "Sink-holes." This Sculptured Earth: The Landscape of America. New York: Columbia University Press, 1959.

Skirvin, Raymond Taylor. "The Underground Course of the Santa Fe River Near High Springs, Florida." University of Florida Thesis, 1962.

Stewart, Joseph W. "Synoptic Remote-Sensing Survey of Lakes in West-Central Florida." Presented at the NASA Second Annual Earth Resources Aircraft Program Status Review, 1969.

Stringfield, V. T. Artesian Water in Tertiary Limestone in the Southeastern United States. United States Geological Survey Professional Paper 517, 1966.

Stringfield, V. T. and Le Grand, H. E. Hydrogeology of Limestone Terranes in the Coastal Plain of the Southeastern United States. Geological Society of America Special Papers, No. 93, 1966.

Stringfield, V. T., and Le Grand, H. E. Hydrology of Carbonate Rock Terranes - A Review. Journal of Hydrology, Vol. 8, No. 3, 1969.

Sweeting, M. M. Hydrogeological Observations in Parts of the White Limestone Areas in Jamaica. Kingston: Geological Survey, 1955.

Swinnerton, Allyn C. Hydrology of Limestone Terranes, Physics of the Earth IX. New York: McGraw-Hill Book Co., Inc., 1942.

Tebeau, Charlton. A History of Florida. Coral Gables: University of Miami Press, 1971.

Thornbury, William D. Principles of Geomorphology. New York: John Wiley & Sons, Inc., 1969.

Tobacco Institute, Inc. (The). Florida and Tobacco. Washington, D. C., 1960.

Tyson, Willie Kate. "History of the Utilization of Longleaf Pine (Pinus palustris Mill) in Florida from 1513 until the 20th Century." University of Florida Thesis, 1956.

United States Census of Agriculture, 1954, 1959, 1964.

United States Department of the Interior Geological Survey. National Atlas of the United States of America. Washington, D. C., 1970.

United States Department of the Interior. The Mineral Industry of Florida. Preprint from the 1970 Bureau of Mines Minerals Yearbook.

United States Soil Conservation Service. Florida Conservation Needs Inventory, 1958 and 1966.

Vernon, Robert O. Geology of Citrus and Levy Counties, Florida. Florida State Geological Survey Bulletin No. 33, 1951.

Vernon, Robert O. Report to the Legislature, Sinkhole Probability. Florida State Geological Survey, 1969.

Vormelker, Joel David. "Geology of the High Springs Quadrangle, Florida." University of Florida Thesis, 1966.

White, William B., Watson, Richard A., Pohl, E. R., and Brucker, Roger. "The Central Kentucky Karst." The Geographical Review, Vol. LX, No. 1, 1970.

Yon, Jr., William J., and Puri, Harbans S. "Geology of Waccasassa Flats, Gilchrist County, Florida." Bulletin of the American Association of Petroleum Geologists. Vol. 46, No. 5, 1962.

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Elizabeth Morgan Furr Abbott was born in Atlanta, Georgia. She attended public schools in Fulton County, Georgia, and in Indian River County, Florida. She is married, the wife of James B. Abbott III, and the mother of four children, James B. Abbott IV, Charles M. Abbott, John S. Abbott, and Elizabeth M. Abbott.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James R. Anderson

James R. Anderson, Chairman
Professor of Geography

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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